

What is in a *Nature* Paper?

TODAY a new guide to authors is published. This is hardly a momentous event but it does provide an opportunity to discuss in some detail both the form and the content of material submitted to *Nature*. Any journal that attempts to span the sciences and, in addition, is constrained in the number of papers that it can publish is bound to be subjected to continued questioning both internally and externally.

Is there any future for a journal like *Nature* that tries to skim the cream of many sciences and, what is more, claims that its papers should be readable by those beyond the immediate confines of the speciality? At a time when a typescript can be submitted, refereed, printed and published in three months in some specialist journals, what attraction does a general journal have as a vehicle for publication?

The most obvious answer, and the one most commonly given, is that the existence of *Nature* allows a scientist with an idea which he thinks has implications beyond his own field to tell it to the community at large, and that this is a good thing. No doubt there is something in this, although perhaps less than is sometimes claimed. Much lip service is paid to cross fertilisation and conferences are devoted to bringing together different disciplines but many of these have all the features of sporting encounters. The sides arrive separately, are intent on demonstrating their own skills, are unimpressed or ignorant of the skills of others and retire to separate dressing rooms at the end. The actual transmission of ideas between disciplines is probably most effectively done by a very few bright people prepared to spend months reading, talking and thinking.

Nonetheless papers in *Nature* do get read and understood by more than the specialists and for want of a better term we call this 'reading for pleasure'. There is a large readership genuinely interested in where science has got to and what problems are being attacked this year. The wide range of correspondence received in the *Nature* office indicates clearly that this interest in the results of present research is not confined to scientists. Moreover, in many parts of the world the library budget restricts very severely the number of specialised journals available. Here *Nature* plays an even bigger role. It is not functioning simply as a journal for announcing results and providing reading for pleasure—for some it is the only way to keep abreast.

We thus see no reason why a general journal should not flourish and should not, with some justification, invite scientists to continue to send material to it.

The obvious follow-up question is—what material? *Nature* clearly cannot claim to be all-embracing. In some fields, in spite of corrective action in "News and Views", papers are rare. This is not the result of any conscious policy; indeed we would welcome more frequent contributions in, say, nuclear physics, but the structure of some branches of science is now so mature, even middle-aged, that the specialist journals provide all that practitioners need. It cannot be denied, however, that there is among

scientists a general body of ignorance which leads to antipathy towards developments in fields in which authors rarely reach out to a more general readership.

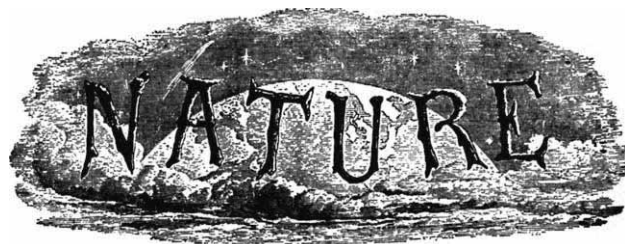
The qualities that are sought in manuscripts are immediacy, wide interest, clarity and plausibility. We seek first to have some positive reason for publishing, and a reason which is related to the state of science at present. Will we be impeding science by declining to give the paper a rapid, wide circulation?

We next ask whether the paper will have a broad appeal. It is not easy to determine the breadth of appeal but many authors make our job even more difficult by failing to provide an inkling of why the paper is appealing. It is not good enough for a paper to be technically correct; it must do a certain amount of self-advertisement. Most readers are not prepared to pitch into a paper unless they have some idea what it is about. It is surprising how little the journalist's most elementary skill has permeated the scientific profession—the first paragraph tells the story, the rest fills in the details. We venture to suggest that a good uncomplicated first paragraph more than doubles the numbers of those who will read a paper right through and ensures an enormous increase in those who will at least give the paper attention for a brief period.

Finally, plausibility. Does the paper carry a message which a reasonable man could take seriously? Does it hang together? Does it avoid the devious? It is easier to define plausibility through such questions than through assertions. Plausibility does not rule out controversy, but it does eliminate irrationality.

One rather well-worn hurdle remains—brevity. We give some guidelines about the upper limits to length, fully expecting these limits to be breached. Nevertheless it bears repetition that the size of *Nature* is limited, so long papers simply exclude others. Authors are well advised to think carefully whether they are planning an

100 Years Ago



THE Cape mail brings word that the *Challenger* has arrived at Simon's Bay. On her voyage from Bahia she touched at Tristan d'Acunha, and made a survey of the groups of islands to which it belongs. Two Germans were found who had lived there for a couple of years, and who gladly availed themselves of the opportunity of leaving.

From *Nature* 9, 92, December 4, 1873.



article or a letter. Letters tend to have a more immediate urgency and articles a more expanded viewpoint; it would be wrong to regard a letter as a failed article. We deliberately make no distinction in textual type size between the two, in order not to diminish the great importance we attach to letters.

Some of *Nature's* distinctive requirements, sometimes criticised, should be viewed in the light of a desire to publish more papers. Expansive and fulsome acknowledgements are frowned upon—A. V. Hill's splendid send-up (*Nature*, 175, 266; 1955) is well worth reading. References are numbered but the idea is not to irritate by adopting a system different from most others, rather to save up to half a line per reference. Thereby we can publish perhaps three more letters per week. For similar

reasons, the number of references should be kept firmly in check.

With the absorption of *Nature Physical Science* and *Nature New Biology*, it is only reasonable to ask whether there is to be less space for papers which in the past three years have gone to the 'satellites'. The answer, in the short term, is no. The situation in the medium and long term depends as much as anything on trends in science and the world shortage of printing paper. We are, however, adding a section as an experiment. 'Matters' butions following up earlier material. It is more extensively described below.

It is impossible to run a journal that tries to be selective without generating mixed feelings and some controversy. We shall continue to attempt to avoid blandness.

Guide to Authors

MANUSCRIPTS submitted to *Nature* must contain original work and not be under consideration elsewhere simultaneously. The Editor is guided by referees and his decision on acceptability is final. The editorial staff cannot discuss decisions over the telephone.

Nature accepts three types of communications: Articles, Letters, and Matters Arising. Articles are up to 3,000 words in length with at most six figures and may either be reports of major research developments in a subject or broader reviews of progress. *Nature* commissions many of the latter and authors considering preparing a review are urged to consult the Editor first. Letters are brief reports of research of unusual and wide interest. They should not in general be longer than 1,000 words; at most they may have three or four figures. 'Matters Arising' is a new feature intended to permit occasional short discussion of papers that have previously appeared in *Nature*. A limit of 350 words is placed on contributions in this category. Points raised in 'Matters Arising' must have the same general interest and substantive character that is expected of original *Nature* papers. Authors will be invited to reply briefly to such discussion of their work; the Editor will decide on suitability of any exchange for publication, if necessary after consulting a referee.

Manuscripts should be submitted either to London or Washington but manuscripts declined by one office will not be reconsidered by the other. Two typed copies should be submitted, each including lettered copies of figures. Typing (including references) should be double spaced. The title should be brief and informative. Pages should be numbered. References, tables and figure legends should start on separate pages. Authors are reminded that experimental detail vital to the paper yet which would interrupt the narrative is best placed in the figure legends. Units should conform to the *Système International*. Greek characters should be identified in the margin on their first appearance. Equations should occupy single lines if possible. $\exp(a)$ is preferred to e^a if 'a' is more than one character.

Articles should be accompanied by an abstract of not more than fifty words, and the abstract should list the main conclusions that are drawn. Sub-headings

may be supplied for articles, but should carry more information than, say, 'Introduction', 'Experiments', 'Conclusion'.

References are indicated by superscripts in the text. The style of references may be gleaned from any contemporary *Nature* with the following two changes:

(i) If it is necessary to refer to several references by the same author at once, only one reference number need be given.

(ii) The last page as well as the first of any reference should be cited.

Abbreviations for references should follow the *World List of Scientific Periodicals*, fourth ed., (Butterworth, 1963–65). 'Personal communication' and 'unpublished work' do not go in to references and should be incorporated in the text. Papers in preparation and submitted for publication likewise should not appear in references—'in the press' is the earliest that a paper may be referred to. Footnotes are not permitted.

Acknowledgments should be brief. Grant numbers, statements that the work is contribution number 999 of the institute, declarations that the director has authorised publication or announcements that the order of authors has been chosen by lot are not printed.

Original artwork should be sent with the manuscript. All artwork should be clearly marked with the author's name and an indication of which way up it is to appear. Line drawings should preferably be in Indian ink on heavy cartridge paper, although other materials are acceptable; however, thin, shiny, folded, torn or heavily handled material should be avoided. Matt rather than glossy photographs are preferred. Figures are usually reduced to one column width, and the originals should be about twice their final size. Figures, particularly maps, should contain nothing but essential material. It is preferred that the original be unlabelled but with an attachment of the same size containing the appropriate lettering. Labelling on photographs should if possible be avoided entirely.

The Editor will be glad to answer questions on any matters relating to this guide.

NEWS

New Rules for Biomedical Research Projects . . .

by our Washington Correspondent

FUTURE participants in biomedical research projects in the United States may have good cause to be thankful for the publicity accorded to some 200 black men from Tuskegee, Alabama, who took part, without their knowledge or consent, in one of the most highly publicised medical research scandals to come to light in recent years. The furore that broke out when details of the project were unearthed last year has led to a searching re-examination of ethical standards in clinical research and the prospect of a set of new regulations designed to safeguard the rights of experimental subjects in such research.

The Tuskegee study, as it quickly became known, was originally sponsored by the federal government and was designed to determine the clinical effects of syphilis and the efficacy of treatment for the disease. The procedure was simple. A number of poor black men from rural Alabama who were known to have syphilis in the 1920s were denied treatment for some 40 years while the course of the disease was monitored. None of them was ever told that he had syphilis, many died and the rest were quietly forgotten until the whole affair hit the headlines.

The Department of Health, Education and Welfare (HEW) immediately set up an official inquiry into the matter, and the committee had little difficulty in concluding that the study was ethically unjustified. The Tuskegee study had, for a start, violated the cardinal rule in human experimentation—that subjects should be informed of the likely risks and that they should freely consent to take part. Moreover, no risk-benefit analysis of the study could conceivably have shown that the benefits to be derived would ever outweigh the risks to the unfortunate men who unwittingly took part.

The committee also suggested that the present guidelines governing clinical research are vague and that they are probably not strict enough to discourage less scandalous, but still unacceptable, research projects. In the meantime, Senator Edward M. Kennedy was holding a series of hearings with his Senate Health Subcommittee which bore out the committee's fears in brutal detail. Kennedy's hearings turned out to be a nicely stage-managed exposé of a number of research projects whose ethical foundations ranged from outrageous to merely dubious.

The upshot of Kennedy's hearings was a bill to strengthen the review procedures for all research projects involving human subjects, to establish in the federal government a high level board to draw up policies for protecting research subjects, and to ensure that the policies will be implemented at the institutional level. The bill has been passed by the Senate, but it is now in limbo, awaiting a conference committee to put it into final form.

The Administration has also been busy, for apart from setting up the com-

mittee to investigate the Tuskegee study, the Department of HEW has recently proposed a set of guidelines which will eventually require institutions in receipt of HEW grants to tighten up their control of experiments involving human subjects. Finally, an *ad hoc* committee consisting of members of the National Institutes of Health (NIH), the National Institute of Mental Health and the Food and Drug Administration last week published a draft report recommending tight controls on research involving children, prisoners, the mentally

EDUCATION

Open to All?

THE Vice Chancellor of the Open University, Dr Walter Perry, persuaded the producer of *Coronation Street* to enrol Mrs Clegg, who keeps the corner shop, at the Open University. Sadly her progress is rarely mentioned, but she has at least helped to ensure that 40% of the British population have heard of the Open University.

Dr Perry gave the third Shoenberg memorial lecture to the Royal Television Society last week. He described how the Open University has coped with the momentous task of giving a university education, at a distance, to students of whom no formal entrance qualification is asked.

Very little has been spent on advertising, and consequently Dr Perry considers the number of people who have heard of the Open University as quite encouraging. But the 60% who have not heard of it are mainly from the lower socio-economic groups, for whom it was primarily created.

Of the 36,000 or so prospective students who have applied each year, 10% have no academic qualifications and 30% have some qualifications, but less than those required by other British universities. The remainder could have entered a more conventional British university.

The Open University is thus not yet appealing to those it wishes to attract. Many have obviously not heard of it, and Dr Perry feels that some have a typically British suspicion of all things intellectual.

How do the unqualified 10% fare? Courses assume no previous knowledge but progress quickly. During the first three months of tuition slightly more unqualified than qualified students drop

out. Of the ones who progress further the unqualified students perform indistinguishably from the others in arts subjects, slightly less well in science and technology and very badly in mathematics. The cure for this has not yet been found: should the first year mathematics course be altered? Should the Open University alter its philosophy and impose entrance requirements for mathematicians, or should it provide pre-university mathematics courses itself?

Everyone is agreed that the courses for the first two years should be general in scope but many students now approaching their third and fourth years wish to progress to more specialised courses. Some members of the Open University are ready to provide them; others contend that the educationally deprived students who have yet to enrol in large numbers will not want conventional specialised courses. There is not enough money for both types of course and discussion is heated.

The drop-out rate in many conventional correspondence courses is about 90%. Dr Perry and his colleagues have, however, managed to keep the rate below 30%, partly by modelling several features of the Open University, such as the week-long summer school, on the similarly successful correspondence University of New England in Armidale, New South Wales. Revolutionary teaching methods such as home experiment kits and tape recordings have quickly become incorporated into courses.

The Open University is no longer a topic of party political dispute, and the sale of its courses for use in other universities may make it the most cost-effective university in the world. If it can succeed in appealing to the section of the population it has not yet touched, its success will be remarkable.

infirm and other special cases.

The publicity given to research projects that are plainly outrageous has, however, tended to overshadow some of the more delicately balanced arguments and concerns. For example, what controls should be applied to research on children who lack not only the legal capacity to give their consent to take part but who may also be unable to understand the possible risks? Another area fraught with difficulty is research on prisoners—for example, is a man who is denied basic freedoms and who is continuously subject to the will of prison authorities truly free to give his consent to anything? Moreover, does the opportunity to take part in a research project which will relieve the routine of prison life and which may involve other large rewards carry undue incentives which, to him, outweigh the risks? (More than 70% of preliminary human testing of drugs in the United States is carried out on prisoners.) Equally difficult questions are raised in connection with research on the mentally retarded, on fetuses and on pregnant women.

It was those tricky questions that were faced by the *ad hoc* NIH committee, whose recommendations were published last week in the *Federal Register*. The committee believes that controls on such research should be greatly strengthened at both the federal level and in the institution in which the experiments will be conducted and it also suggests a few cases in which human experimentation should be outlawed entirely.

As far as research on children is concerned, the committee suggests that any proposal should be reviewed for ethical considerations by at least three committees, two of which would be in the institution in which the research is to be carried out and one in the agency sponsoring the research. It would work like this. Before submitting a proposal to HEW for funding, the project must be reviewed by an Organisational Review Committee, consisting of members drawn from a variety of disciplines, some of whom would not be employed by the institution concerned. Once the committee has approved the experimental procedures, the proposal would then be sent to HEW, where it would be subjected to the usual peer review system for scientific merit. The next stage is review by special committees to be established in every agency of HEW. These Ethical Review Boards would again consist of members from various disciplines and, as well as examining individual projects, they would advise the agency on general ethical issues.

Once approved by this process, the project would then come under the supervision of yet another institutional review committee, the Protection Com-

mittee. Its duties would be to ensure that those who take part in the experiment are fully informed of the risks, and that their consent and that of their parents is freely given. The Protection Committee would also be on hand to make sure that participants could pull out at any stage if they so wished.

In addition to that mechanism, the committee also suggests a number of other criteria that should be met before research can be carried out on children. First, the consent of both parents should be obtained. Second, the consent of any child over the age of seven who takes part in an experiment should be obtained. Finally, children without natural or adoptive parents, or those detained in an institution or in court, should be excluded from participating.



Senator Edward Kennedy

As for research on prisoners, the committee notes that it is ultimately up to the courts to decide whether prisoners are in a position to give consent without undue coercion, but it points out that in the meantime HEW should adopt a set of regulations which afford prisoners as much protection as possible. In short, the committee suggests that a project involving prisoners should come under the purview of a Protection Committee consisting of at least five members, one of whom would be a prisoner. It would make sure that those who take part are given full information and that they are not offered undue incentives.

Finally, the committee suggests that research should be carried out on the mentally infirm only if it can be proved that the study cannot be accomplished with the use of other volunteers; that no research should be performed on the abortus if it involves prolonging the heartbeat and respiration or, conversely, if it will of itself terminate the heartbeat; and that no research involving implantation of human ova which have been fertilised *in vitro* shall take place until animal studies have indicated that it would be safe (and that includes studies of the naturally born offspring of the products of *in vitro* fertilisation).

MORE ON MEDICAL ETHICS

... But Britain Differs

CLINICAL research investigations of children and mentally handicapped people should be allowed, according to a committee of the Royal College of Physicians. In a report published today on the *Supervision of the Ethics of Clinical Research Investigation in Institutions* (£0.10 from the Royal College) the committee says that to ensure advances in medical treatment research must continue, even though the investigations might not be of direct benefit to the patient.

The committee adds, however, that the investigation should be carried out "only when the procedures entail negligible risk or discomfort and subject to the provisions of any common, or statute, law prevailing at the time".

The Royal College document is in sharp contrast to the report of the *ad hoc* committee of members of the National Institutes of Health, the National Institute of Mental Health and the Food and Drug Administration published last week in the United States (see page 239). The report from the United States, which is likely to be incorporated into firm proposals by the Department of Health Education and Welfare, recommends much more stringent controls on clinical research than does that from the Royal College.

The Royal College report is a sequel to one published by the same body in 1967. Sir George Godber, Chief Medical Officer at the Department of Health and Social Security (DHSS), wrote to the late Lord Rosenheim, then president of the college, in 1971 asking him to investigate further the supervision of the ethics of clinical research in institutions. In particular, Sir George asked advice about the composition of ethical committees and the scope of clinical investigations.

The advice now given to the DHSS is that ethical committees should be small and should be constituted so that they do not "cause an unreasonable hindrance to the advancement of medical knowledge". The members should be experienced clinicians but there should also be one lay member. The committee stresses that this lay member must be someone "who is not associated with the [medical] profession in any paramedical activity". Biochemists and psychologists are therefore ruled out.

In view of the uncertainty about the procedures which have to be referred for approval, the Royal College advises that application should be made to an ethical committee "for all proposed clinical research investigations". The committee stresses the fact that a drug which has been granted a Clinical Trial Certificate or a Product Licence by a Licensing Authority on the recommend-

ation of the Committee on Safety of Medicines "in no way absolves the ethical committee from investigating the ethical aspects of that trial".

Patients who are undergoing tests which are not intended for their benefit should be given a full explanation of the proposed procedure and the patient should feel free to withdraw from the tests at any time, says the committee. Except for trivial procedures of which venapuncture is an example, an explanation of the procedure should be given in the presence of a witness.

When the research is intended for the benefit of the patient the committee feels that there are circumstances in which it would be "inappropriate or even inhumane" to give detailed explanations of the procedures involved. Such cases should be investigated with particular care by the appropriate ethical committee.

SOVIET SCIENCE

Land and Sea

LUNOKHOD-2, which landed on January 16, 1973, in the Le Monnier crater on the eastern edge of Mare Serenitatis, had a region of particular selenological interest to explore—the transition from mare to highland. Operating among features assigned unofficial working names such as 'Head-on Hills', 'Shallow Crater', 'Round Bay', 'Near Cape', 'Far Cape' and 'Straight Rille', the Lunokhod recorded and transmitted data of considerable significance, not only to the interpretation of this specific type of area but to lunar research as a whole.

One of the most important experiments of Lunokhod-2 was the determination of possible changes in chemical composition of the transition area surface. A modified version of the RIFMA X-ray spectrograph used on Lunokhod-1 was used—the new instrument, RIFMA-M, being specifically adapted to determining the ratio of iron to other elements—notably aluminium and titanium. Near the landing site, on the slope of a crater of diameter 40 m, readings of Si, $24 \pm 4\%$; Ca, $8 \pm 1\%$; Fe, $6 \pm 0.6\%$; and Al, $9 \pm 1\%$ were obtained. (The iron reading obtained by Lunokhod-1 for Mare Imbrium was 10 to 12%.) As Lunokhod-2 moved southwards, towards the 'Head-on Hills' on the edge of the highland, no significant changes were at first observed—data from a 13 m diameter crater at approximately 1.5 km from the landing site were close to the first readings. But as it moved closer to the hills the iron content decreased and 5 km from the landing site it had fallen to $4.9 \pm 4\%$. On February 19 a minimum reading of $4.0 \pm 0.4\%$ was obtained. During this part of the survey, the aluminium content increased to $11.5 \pm 1.0\%$. Writing

in *Pravda* (November 20, 1973), Academician A. Vinogradov and Dr S. Solokhov attribute this change to a general variation in regolith composition in mare-to-highland transitions.

Panoramic television surveying of the transitional region revealed a number of interesting features, including a crater of diameter 15 to 20 m in the neighbourhood of the 'Head-on Hills' with associated slip terraces of some 10 to 15 m. In this region the density of small craters (diameter 2 to 3 m) fell to one half to one third of the average maria density.

A particular object of investigation was the 'Straight Rille', which stretches for some 15 to 16 km in a north-south direction along the south-east edge of Le Monnier. On both the eastern and western edges of the rille, a 30 to 40 m zone of intensive shear towards the fault was observed. The thickness of the regolith decreased as the lunokhod approached the rille and the lip consisted of a rock 'border' with boulders of diameter at least 1 to 2 m.

One interesting feature of the Lunokhod-2 programme was an attempt to correlate chemical composition to visual observation of the albedo. Using photometric telephotography from Earth and the RIFMA-M observations, a general relationship between the readings has been established. This is a result which is considered by the Soviet team to "extend considerably the significance of the Lunokhod-2 results".

The magnetometer experiments, a new feature of Lunokhod-2, revealed some characteristic variations in the field attributed to induction currents produced by variations in the interplanetary field. These data, it is claimed, should reveal the conductivity of the Moon to a depth of some hundreds of kilometres.

NUCLEAR WEAPONS

Poor Security

by our Washington Correspondent

LAST month, when fighting in the Middle East was at its peak, the United States Atomic Energy Commission (AEC) ordered security to be stepped up at all institutions which handle enriched uranium and plutonium, to ensure that none of the material could be stolen and end up as part of a nuclear finale to the Arab-Israeli conflict. The extra precautions were, it seems, more than justified, for a recent investigation by the General Accounting Office (GAO) has come up with the disturbing finding that security arrangements in some plants which hold strategic nuclear materials would pose few problems for a ham-fisted amateur burglar, let alone a terrorist organisation.

The most expensive, lengthy and diffi-

cult part of making a nuclear weapon is the production of fissionable material, but fabrication of the weapon itself is reckoned to be a relatively easy task which would not be beyond the wit of scientists in most countries. Thus, if a supply of enriched uranium or plutonium could be diverted from installations in the United States, probably over a period of time, nuclear weapons could be within reach of those willing to pay the price. A crude bomb, such as the ones dropped on Hiroshima or Nagasaki, would require some 17 kg of enriched uranium or about 6 kg of plutonium, and it would, of course, take only one such bomb—or the threat of it—to upset the military balance in the Middle East.

The AEC itself acknowledged such risks in an internal report in 1971, which came to the conclusion that "as long as significant quantities of nuclear materials are in active use by the government, by government contractors, and by licensed commercial and other interests, there will be a distinct probability that some of those materials will be stolen, unexplainably or accidentally lost, diverted from authorised use, or used or disposed of in unauthorised ways".

With such considerations in mind the GAO, which carries out investigations for Congress, inspected the security arrangements in three plants which hold strategically important quantities of special nuclear material (as enriched uranium and plutonium are called). It found that in two of the plants, security "was so limited that protection was inadequate".

This is what the GAO found at one of the plants which, mercifully, remained nameless. The plant was protected by a part-time security officer and four armed guards, one of whom was on duty at all times, and it was surrounded by an 8-foot high wire fence. Special nuclear material, some of which is described in the report as being "of high strategic importance", was located in three buildings just inside the fence. Entrances to the building were connected to an alarm system.

On the face of things, that seems a fairly good security system, but the GAO found that it had the following defects:

- The fence had thirteen weaknesses, ranging from broken welds to inoperative locks, which would allow it to be breached with ease. Ten of the weaknesses were out of sight of the guard post.

- One of the storage areas was a prefabricated structure, just 16 foot from the fence, made from sheet steel panels 3 foot by 9 foot. According to the GAO investigators, who tested the strength of the panels with an adjustable spanner, "within 1 minute we were able to remove five metal screws from

one of the panels. At this point, the only impediment to entry was a small rivet which, in our opinion, could have been forced manually". Moreover, within 30 seconds, the investigators cut a 19-inch section of the panel with tin cutters.

- The door to the building could be opened easily because the lock had been broken, and it could be opened without activating the alarm.

- A second storage area could easily be entered through a vent in one of the walls. "With little effort", the GAO report states, "the louvres could be pulled out by hand and the inside screen could be manually forced, providing access to the building interior".

- Once inside the building, an intruder would have little difficulty in obtaining special nuclear material because it was stored in portable containers, which were "readily accessible". Moreover, plant personnel rarely entered the storage areas in the evening and night shifts, and the guards made regular rounds which could easily be monitored.

- Finally, all external means of communication at the plant were handled by a single cable, which entered the facility at a point which the guard could not see from his post. "Severing this cable would eliminate all means of timely communication with outside law enforcement agencies", the report notes.

The AEC says that it has taken steps to remedy the specific deficiencies outlined in the GAO report and earlier this year it issued a set of new regulations to tighten security at plants containing special nuclear materials. Nevertheless, the report does little to establish public confidence in the AEC's ability to keep an eye on its contractors and licensees, and it neatly underlines one of the arguments that critics of nuclear power have been persistently raising in the past few years.

It is frequently argued that proliferation of nuclear power plants will lead to an increase in the quantities of enriched uranium and plutonium in the United States, which will greatly increase the problems of ensuring that none of the material gets diverted into dangerous hands. At present, there are some ninety-five facilities in the United States which have at least 5 kg of weapons-grade nuclear material but by 1980 the AEC estimates that more than 1 million kg of special nuclear material will be required for the domestic power industry. Moreover, when the fast breeder reactor starts producing electricity in the 1980s, it will also start producing large quantities of plutonium. The extra precautions taken during the Middle East war will clearly be required on a longer term basis.

Short Notes

Crisis Under Control

STOPPING over in a power-reduced London on his way from a power-reduced Washington to a presumably warm Moscow, Dr Guyford Stever, director of the National Science Foundation and Science Adviser to President Nixon, paused long enough to tell a group of shivering journalists at the United States Embassy (where they take these things patriotically and the conference room central heating was down 20 degrees from the previous week) that the United States is going to more than double its expenditure on energy research over the next five years. A few years ago, Dr Stever said, about \$400 million was spent each year on energy research. This year it was between \$700 and \$800 million. Next year it would be \$1,000 million and over the next five years \$10,000 million.

Nonetheless, Dr Stever said, there will be a serious energy shortage in the United States for the next five years. The solution, he believes, lies in exploring coal liquefaction and gasification and in energy conservation. Fusion, he said, might be with us by the year 2000, although the enormous capital investment involved might make its progress slower than some people believe. Solar energy might also be making a contribution by then.

At any rate, the United States is determined as soon as possible to become completely independent of any other country for its energy. The Arabs, Dr Stever added, had precipitated the energy crisis in the United States but it was a problem that was coming anyway.

As for nuclear reactor safety, proper engineering and design can "easily handle" the problems. There is always a small danger, he said, but then no member of the public has ever been killed or seriously injured by an atomic accident in the United States.

Critical Difference

A ROW is brewing in the United States over just how severe the energy crisis is likely to be this winter. According to President Nixon and other Administration spokesmen, supplies of oil will be between 10 and 17% short of demand when averaged out across the country and the crisis, although severe, will not result in undue hardship. But according to a study carried out by the Library of Congress and published last week in the *Congressional Record*, the shortfall could reach a staggering 35% if the weather turns out to be unduly cold and if there is no relaxation of the Arab oil embargo. Moreover, even if the winter is relatively mild and Middle East oil starts flowing again soon, the

Library of Congress reckons that the gap between supply and demand will still be 20%.

The chief difference between the forecasts is that the Administration's sanguine predictions would probably not require rationing of petrol and heating oil, whereas the more pessimistic predictions of the Library of Congress almost certainly would. The disagreement is not, however, restricted to a battle of words between members of Congress and the Administration, for some of the President's own advisers are unhappy about the effects on public opinion if the Administration's reassurances turn out to be without foundation.

Australian Research

THE annual report of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia for the year ending June 30, 1973, reveals that the total expenditure of the organisation increased by \$A6.17 million to \$A73.7 million during the year.

The report states that CSIRO is at present undergoing a significant re-orientation. In the past it has been "industry oriented" but it is now striving to become "people oriented". To achieve this aim the organisation is, for example, changing the tone of its environmental research so that its relevance to industry is "more tenuous".

With this change of emphasis the report states that there is a need for a more effective communication "with the community as a whole". The organisation is taking steps to meet these needs but gives no details of the procedures involved.

Nixon's Economy

SOON after exhorting all Americans to conserve energy to help stave off a potential crisis this winter, President Nixon boarded his presidential airliner for a weekend trip to Florida. According to the White House, the return journey used up 8,000 gallons of fuel. According to the *Washington Post*, which is not one of Mr Nixon's most ardent admirers, that amount of fuel would have allowed one commuter to travel from the outskirts of Washington to his office and back every day for 11 years. Mr Nixon did, however, order the pilot of his aircraft to slow down to 475 miles an hour, thus saving 200 gallons of fuel an hour.

Mars for 10p

A 'street astronomer' has been spotted in London's Shaftesbury Avenue. Armed with a 75-mm telescope and sky maps, he offers passers-by a view of Mars for 10p (*Junior Astronomical Society Circular*, No. 57; November 1973).

NEWS AND VIEWS

Role of Sex-linked Histocompatibility Antigens

CURRENT interest in histocompatibility antigens, apart from technical problems concerning their investigation and practical problems connected with transplantation in man, largely centres on their biological role. As has been frequently pointed out, it is difficult to believe that such a major genetic investment has no biological importance. Differing views on the biological role of the major histocompatibility locus in any species, including HL-A in man and H-2 in mice, have been expressed, ranging from those who see them as connected in some way with the generation of immunoglobulin gene diversity, and those who consider that their function is concerned with the maintenance of the integrity of the individual, being involved in protection either against neoplasms or against the potential invasive problems which accompany the evolution of viviparity. These views have recently been discussed in the pages of *Nature* by Bodmer (237, 139; 1972) and Burnet (245, 359; 1973).

It is also legitimate to ask, however, whether the 'minor' histocompatibility loci, and indeed other antigenic polymorphisms such as the ABO blood group system in man, also play a part in the functions suggested for the major histocompatibility locus. Some of the minor loci in the mouse, the only species studied in any detail, seem to be almost as complex as H-2, and once again it would be good to think that such a major genetic investment supposes some biological function. Is this function a modification or elaboration of the functions of the major locus, or do the minor loci have some distinct part to play?

If such questions become puzzling for the minor autosomal loci, they become positively bewildering when related to X and Y-linked histocompatibility antigens. Whatever the significance of histocompatibility loci in general, X and Y-linked H loci are clearly a very special case, and many of the possible functions of autosomal loci clearly cannot be carried out by sex-linked loci. There is much less hard information about the X and Y-linked antigens, partly because of the technical problems of their investigation. Recently considerable advances in knowledge of one such system, the H-Y antigen in the mouse, have been made, stemming from the technical advances in detection of H-Y antigens made by Boyse and his colleagues.

The results of one such study by Bennett and Boyse are reported on page 308 of this issue of *Nature*. They reinvestigated the question of whether immunisation against H-Y antigens in female mice might alter the sex ratio in their progeny. They remind readers that such investigations have been conducted before, but always by attempting to immunise the female *in vivo*, and that such investigations have always been negative or equivocal, but that it was previously impossible to decide which of the many possible reasons for this failure to demonstrate immunoselection was correct. They exposed sperm to anti-H-Y and complement *in vitro*, and then artificially inseminated females, and did indeed show a small but statistically significant decrease in the proportion of male offspring in litters of such females.

Bennett and Boyse discuss, in an admirably cautious way, the conclusions to be drawn from their observations. Two points may be emphasised. One is that this is some evidence that the H-Y gene may be concerned with the sex ratio, a conclusion which one would hesitate to make *a priori* when one considers the ragbag of genes known to be present on the sex chromosomes. The other point that should be stressed is that although the alteration in the sex ratio observed is small, and complete elimination of male offspring was not achieved, the alteration in the sex ratio was from 53% males in untreated litters to 45% in experimental litters, that is, an increase of 8% in the proportion of females. Although small, one can imagine many situations in farm livestock where such a change, if accompanied by no decrease in fertility, would be of considerable economic importance.

From a Correspondent

Hot Spots Must Move

IF linear chains of volcanoes in the ocean basins originate as outflows from localised regions near the Earth's surface—hot spots—over which plates have moved during geological times, then these hot spots cannot have formed a fixed frame of reference during the past 40 million years. This is the conclusion of Molnar and Atwater in this issue of *Nature* (page 288). This result has major implications for the hot spot hypothesis as there has up to now been a hope among geophysicists that hot spots might have been semi-permanent features and thus good markers of absolute motion of plates over the mantle. The implications, however, go beyond the geometry. If hot spots are not stationary relative to each other, there are serious questions to be asked about their physical character and how it permits them to migrate.

Since the idea of very active volcanic sources leaving their trace on plates was revived by Morgan three years ago, many groups have attempted to use the concept to learn more about past motions. The results have been strangely inconclusive. The one undeniable thing from the geological and geophysical evidence is that the long traces ending in present day volcanoes do indicate something other than pure chance. Many geophysicists would further agree that there is something global to the traces—they are not ten or so entirely unrelated phenomena. But beyond there, opinions differ. Are hot spots simply localised lava sources, or do they have any vertical extension? Are the traces markers of pre-existing fractures or can hot spots punch volcanoes in unfractured plate? Present day geometry of the traces, palaeomagnetic data and a reasonable understanding of plate positions for the past 70 million years are all one has to go by at the moment.

Hargraves and Duncan (*Nature*, 245, 361; 1973) analysed palaeomagnetic data and concluded that they were inconsistent with hot spots being stationary relative

to the Earth's magnetic field. Since there are reasonably strong grounds now for assuming that the pole does not wander, it was necessary to assume that the hot spots do. Hargraves and Duncan were able, however, to find a rotation of the mantle as a whole which reproduced their results tolerably well without the need for the migration of individual hot spots. There is thus the possibility that not only do plates move, but the material that they slide over is also in motion.

Molnar and Atwater adopt a geometrical approach which does not use palaeomagnetic evidence directly. They use the now generally agreed upon poles of rotation of plates to run the geological clock back 38 million years. They place the 38 million-year-old rocks on the Hawaiian chain over the present position of the Hawaiian hot spot and see what overlay the other hot spots at that time. None of the linear features lies on top of their presumed parental hot spots when this analysis is carried out. This implies that there must have been relative motion among hot spots in the past.

It is now necessary for geophysicists to consider these two papers very carefully. The authors do not come to identical conclusions, but this is perhaps not surprising. What they do point to fairly clearly is some sort of mobility below the lithosphere—a mobility of up to a couple of centimetres a year. How deep this mobility extends there is as yet no idea, and although it is still possible that the Morgan hypothesis that hot spots are fed by deep mantle plumes is tenable, there are now very serious doubts that such a delightfully simple model can apply. Yet more solid ground of nature is eroded. D. D.

SYSTEMATIC ZOOLOGY

Bearish Carnivores

from our

Vertebrate Palaeontology Correspondent

THE seals, sealions and walruses are normally separated from all other members of the Carnivora by being placed together in a suborder Pinnipedia. It is generally agreed that the pinnipeds are more closely related to the canoid than to the feloid carnivores, and the implication of their placement in a separate suborder is that they all had a common ancestry within the Canoidea. For some time, however, several workers have considered it likely that the otariids (sealions and walruses) whose hind limbs project backwards, and the



Artist's conception of head of *Enaliarctos*.

phocids (fur seals) which can bring their hind limbs forwards beneath the body, originated from different groups of canoids. These workers believed that the otariids were derived from bear-like canoids, whereas the phocids had evolved from otter-like canoids.

Important new evidence on pinnipede origins has been published by Mitchell and Tedford (*Bull. Am. Mus. nat. Hist.*, **151**, 201; 1973), who describe a new early Miocene aquatic carnivore whose skull and dentition are morphologically intermediate between those of terrestrial ursid canoids and those of aquatic otariid pinnipeds.

The new otariid, *Enaliarctos*, is placed in its own new subfamily. Its similarities with the canoids include features of the auditory region which are fundamental in the classification of the Carnivora. This region of *Enaliarctos* is similar to that of early, Oligocene members of the Canoidea, but in several ways is most similar to that of primitive ursids, and to that of the late Oligocene aquatic form *Potamotherium*. (*Potamotherium* has previously been regarded as itself related to the late Cainozoic otters, but Mitchell and Tedford believe that it was already too specialised for aquatic life to be ancestral to them.)

Enaliarctos is also similar to ursids in having retained two quadrangular upper molars, and in the structure of its upper and lower fourth premolars. A natural cranial endocast also shows traces of the 'ursine lozenge' on the antero-dorsal surface of the cerebrum. On the other hand, the skull of *Enaliarctos* shows several similarities to that of otariid (rather than phocid) pinnipeds, and its dentition shows a stage intermediate between that of the primitive ursids and the reduced, simplified pinnipede dentition. Features which suggest an aquatic life include its broadened muzzle and enlarged narial chamber, large dorsally placed eyes and enhanced cranial blood circulation. *Enaliarctos* was also found in marine, near-shore deposits.

Mitchell and Tedford conclude that *Enaliarctos* was closely involved in the ancestry of the Otariidae, and place it in that family. Its similarity to ursids, therefore, leads them to place the Otariidae with its terrestrial relatives

within the superfamily Canoidea, adjacent to the Ursidae. They believe that they have demonstrated a sequence from primitive ursids to otariids that leaves little room for origin of the phocids. The earliest phocids are, like *Enaliarctos*, of early Miocene age. Unless they evolved from a stock closely related to the ancestors of *Enaliarctos*, but already committed in a divergent fashion to an aquatic way of life, there seems little doubt that the phocids are a lineage separate from the otariids. If so, the Pinnipedia is a diphyletic group, and the terms Pinnipedia and Fissipedia should no longer be used.

The Ursidae has also been enlarged recently by Sarich (*Nature*, **245**, 218; 1973), whose immunological studies of the pandas have supported the earlier work of Davis (*Fieldiana, Zool. Mem.*, **3**; 1964) in showing that the giant panda and the lesser panda are not closely related to one another. Instead, the giant panda is merely a highly specialised type of bear. The ursids and procyonids (racoons) are more closely related to one another than to any other canoid. The lesser panda seems to have a separate lineage originating from near the common ancestry of these two families, though perhaps more closely allied to the ursids than to the procyonids. Sarich's immunological studies also support the morphological studies in emphasising the comparatively conservative nature of the Ursidae.

CYCLIC AMP

Regulator of Cell Shape

from a Correspondent

THE proliferation of papers implicating cyclic AMP (3',5'-adenosine monophosphate) as a growth regulator in animal cells is now well into the exponential phase, and even those working in the field may feel justifiably overwhelmed by the amount of new data. Moreover, much of this information is concerned with correlating changes in the behaviour of cells with changes in intracellular cyclic AMP concentrations following relatively complex manipulations, such as exposure to serum or transformation by oncogenic viruses. As more becomes known about possible interactions between different elements of the cyclic nucleotide pathways—for example, the induction of phosphodiesterase by its substrate cyclic AMP and the stimulation of at least one cyclic AMP phosphodiesterase by cyclic GMP—the problem of sorting out exactly where these complex stimuli initially interact with the cell's regulatory programme is greatly increased.

This task would be much easier if it were possible to predict the consequences of selectively altering only one

of the many variables. One way to do this is to isolate temperature sensitive mutants of the different proteins involved in cyclic nucleotide metabolism and the preliminary results of such an approach are described by Willingham, Carchman and Pastan (*Proc. natn. Acad. Sci., U.S.A.*, **70**, 2906; 1973). In order to select for mutants of cyclic AMP metabolism Willingham *et al.* made use of the fact that high levels of this nucleotide enhance the adhesiveness of mouse 3T3 cells to plastic. Cells with low amounts of cyclic AMP would therefore be expected to round up and lose contact with the substratum, and this behaviour was observed in one clone of mutagenised cells, after shifting them from 39° to 23° C. The change occurred within 5 min and disappeared after a few hours at the new temperature, when the cells spread out and re-attached to the dish. This behaviour correlated very neatly with changes in cyclic AMP inside the cells; 2 min after the temperature shift cyclic AMP was at a minimum, but it soon increased and by 2 h reached concentrations up to five times greater than in control cells before declining. Immediately after the temperature change the mutant cells released cyclic AMP into the medium and this, at least in part, accounts for the drop in intracellular cyclic AMP.

Inter alia Willingham *et al.* also observed granular deposits on the dishes in which the mutant cells had been grown for several days. Electron microscope pictures revealed that cell processes were attached to these deposits rather than directly to the plastic but, apart from showing that they contain some protein, the authors were not able to account for this strange phenomenon. The site of the *ts* mutation in these cells has not yet been identified, though adenylate cyclase and phosphodiesterase appear normal. Somewhat surprisingly the transient change in adhesiveness was seen when cells were shifted either up or down in temperature, and there seemed to be no critical temperature at which the cells responded, suggesting that the mutation may not be as straightforward as one would like.

Animal cells with inheritable differences in cyclic AMP metabolism have also been studied by Gilman and Minna, in two papers in a recent issue of the *Journal of Biological Chemistry* (**248**, 6610; 1973). Rather than isolating mutants in the manner of Willingham *et al.*, they surveyed a variety of already existing rat and mouse cell lines for their ability to respond to catecholamines and prostaglandins with an increase in intracellular cyclic AMP. Cells were classified as either β^+ or β^- (responders and non-responders to β -adrenergic stimulators) or P^+ or P^- (responders and non-responders to

prostaglandin E_1). Hybrids made between β^+ and β^- cells were all β^- , at a time when almost all the parental chromosomes were still present, whereas similar hybrids between P^+ and P^- cells were all P^+ . It is tempting to assume that the phenotypes β^+ and P^+ are associated with the presence of receptor proteins in the plasma membrane which are capable of activating adenylate cyclase, but it remains to be seen why the regulation of expression of the two phenotypes is so different.

MEDICAL GENETICS

Penrose Honoured

from a Correspondent

A SYMPOSIUM to commemorate Lionel Penrose, who died suddenly last year during a retirement which had curtailed neither the breadth of his curiosity nor the practical application of his experience to the problems of mental defectives and their relatives, was held in London on November 16 and 17 during the 173rd meeting of the Genetical Society.

The first session was chaired by the President of the Royal College of Physicians, C. A. Clark, who pointed out that Penrose was the first medically qualified holder of the Galton Chair. The session was then introduced by B. Childs (Johns Hopkins University, Baltimore) who exhibited the direct and elegant approaches he is using in the study of patients who have specific difficulties in reading, and was even able to supplement the message of his slides by

exploiting the technical difficulties due to the screen being smaller than the slide image. J. H. Edwards (Birmingham Maternity Hospital) then spoke of the difficulties implicit in the disjunctive use of monogenic and polygenic in observational genetics and the alternative approach of estimating the frequency and strength of the most powerful allele present.

E. T. O. Slater (Institute of Psychiatry, London) then spoke on the hereditary dementias of adult life, with special reference to Huntington's chorea, a condition in which the heterozygote cannot yet be identified in the interval between fertility and morbidity, and sporadic cases cannot be diagnosed with precision. In the final paper of the session, C. A. B. Smith (Galton Laboratory, University College, London) explored yet another of Penrose's interests with yet another parameter defining gametic correlations, this time with the remarkable property that the series of related constants are further related by simple but unusual numerical operations on their subscripts. The final paradox seemed to imply that, so far as gametic correlations are concerned, where, as well as with whom, our ancestors lived may have contributed appreciably to conventional measures of inbreeding.

The next session, which appropriately dominated the meeting, was a video tape presentation by J. Cohen and L. J. Lawler (University of Manchester) and by R. Penrose (University of Oxford), one of Lionel Penrose's three sons. After an introduction of Penrose's works in pencil, woodcut and oil, and

Interaction of tRNA with 5S Ribosomal RNA

SEVERAL years ago it was suggested that the 5S RNA of the 50S ribosomal subunit is important for transfer RNA-ribosome binding. In particular, it was recognised that the sequence UpGpApCp of 5S RNA could interact with the T ψ C loop of tRNA. Evidence has since been accumulating to support this hypothesis; first, it has been shown that the fragment Tp ψ pCpGp specifically binds to a 5S RNA-protein complex; second, non-enzymatic binding of aminoacyl tRNA is inhibited by the same fragment; and, third, two adenines of 5S RNA, which are essential for biological activity and the binding of Tp ψ pCpGp to the 5S RNA-protein complex, are on the surface of the ribosome.

To decide the possible biological significance of these data, Richter, Erdmann and Sprinzl studied the effects of the tetranucleotide (T ψ CG) on tRNA dependent reactions, and they report their results in *Nature New Biology* next Wednesday (December 5). They

found that when the oligonucleotide binds to the 50S ribosomal subunit it inhibits elongation factor (EF)-Tu-directed aminoacyl-tRNA binding, and EF-Tu-linked GTP hydrolysis and ribosome-dependent synthesis of 'magic spot' I. The anticodon loop and the CGA end of tRNA molecules have already been shown to function in protein synthesis. These results show that the T ψ C loop is almost certainly also involved.

As further evidence the authors note that in a recently proposed three-dimensional model of yeast tRNA^{phe}, the Tp ψ pCp is on the surface allowing it, theoretically, to interact with ribosomes, and also that equilibrium dialysis experiments have shown that the T ψ C loop is not base-paired in solution. Although convinced that the oligonucleotide Tp ψ pCp of tRNA binds to ribosomes, the authors are not completely certain that the binding site is on the 5S RNA and intend to investigate this matter further.

the sight, though not the sound, of a remarkable musical composition, complete with semitones, in which the second half was played by inverting the score of the first half, Roger Penrose exhibited an extraordinary series of wooden objects extending from solid representation of impossible objects to relatively simple two-dimensional sliding or slotting puzzles. He ended with a series of self-duplicating objects from the original rhombi demonstrated at the International Genetics Meeting in 1958 in Montreal to self-replicating and self-separating chains of differing units. The remarkable nature of these artefacts was made even more impressive by the manual dexterity of the demonstrator and the depth and lucidity of his commentary. Copies of this tape are available through Professor Cohen (Department of Psychology, University of Manchester).

The symposium continued the next morning, under the chairmanship of J. H. Renwick, with a historical survey and an up-to-date review of the linkage relations of the human red cell groups by R. R. Race (Lister Institute, London). This form of analysis was largely dependent on the work of the Galton Laboratory (under the serial triumvirate of Fisher, Penrose and Harris) where much of the analytical and enzymatic work was developed, and of Race's laboratory at the Lister which provided much of the data, and undertook, by hand, many of the analyses at a speed which defeated the computer. These reviews were followed by R. Ceppellini (University of Turin) who spoke on the linkage relationship of the white cell surface determinants which, unlike those known on the red cell, are defined by several determinants arranged over a segment one or two centimorgans long.

The symposium finished with the Penrose Memorial Lecture, given by Penrose's successor Professor Harry Harris who explored allelic variation in man and reviewed the work of his own laboratory, on electrophoretic evidence of functional enzymatic variants, and related to this data from the mapping of man's best known protein unit of haemoglobin, the beta chain and data on the frequency of those functionless or silent alleles which can be defined by neonatal screening for aminoacidurias.

It was appropriate that a man whose main influence was to expose his own species to the standard of professional scrutiny and objective accountancy established in the genetical study of his parasites, and of his edible and ornamental plants and animals, should be commemorated by a final session in which man was established as the leader, with his own blood, in the objective auditing of claims of selection and chance or, as Kimura might have it, of drift and drive.

HORMONES

Diabetes Control

from a Correspondent

THE role of insulin in the control of plasma glucose concentrations is well known. More recently, the protein hormone glucagon has also been implicated. It has been found that diabetic subjects with high plasma glucose (hyperglycaemia) not only have lower levels of effective insulin activity but also have increased plasma glucagon compared with normal subjects. This may occur because the hyperglycaemic suppression of glucagon release requires insulin. Diabetes is thus a bihormonal disease. Both hormones seem to regulate plasma glucose by their action on the liver, where they are known to have opposite effects on the synthesis and degradation of stored glycogen.

One of the mechanisms by which these hormones exert their opposing actions in liver cells is by stimulation or inhibition of membrane-bound adenylyl cyclase, the enzyme which regulates the intracellular concentration of cyclic AMP (Illiano and Cuatrecasas, *Science*, N.Y., **175**, 906; 1972). Thus it would seem that a decrease in plasma glucagon in a diabetic subject might offset the effect of the lower insulin level. Because glucagon is a protein hormone, one method of depressing its effect would be to produce antibodies against it.

This possibility has now been tested by Epand and Douglas working with immunised rabbits (*Biochem. biophys. Acta*, **320**, 741; 1973). Although bovine, porcine, rat, human and rabbit glucagons are known to be chemically identical, rabbits are still able to produce antibodies to bovine glucagon when the latter is mixed with a suitable adjuvant before injection. Epand and Douglas reasoned that as glucagon is known to stimulate the release of insulin, rabbits whose effective glucagon concentration is decreased by the presence of specific antibodies should have a correspondingly decreased concentration of insulin. Because of the antagonistic effects of the two hormones the resulting concentration of blood glucose should be similar to normal.

To test their theory Epand and Douglas compared the plasma glucose, insulin, and glucagon antibody levels of rabbits immunised with glucagon injections for 4 weeks, with control animals. All the experimental animals produced antibodies to glucagon, but none to insulin. The glucose concentrations in plasma samples of experimental and control animals were virtually the same. The insulin levels of the immunised group of animals, however, were less than half those of the non-immunised rabbits. These results suggest strongly that the presence of glucagon antibodies in immunised rabbits

renders them able to maintain normal blood sugar concentrations with a reduced level of plasma insulin. It is thus likely that the presence of glucagon antibodies lowers the concentration of active glucagon in the plasma which, in turn, decreases the secretion of insulin. The combined reduction of the concentrations of the two antagonistic hormones has little effect on blood glucose.

Epand and Douglas also show that immune rabbits can use administered glucose as quickly as the control rabbits in the glucose tolerance test, but without as great an increase in plasma insulin. The production of glucagon antibodies in a human subject has been reported (Stahl *et al.*, *Horm. Metab. Res.*, **4**, 224; 1972). These results therefore suggest a potential use for glucagon antigenicity in diabetic therapy. Less insulin would be required to maintain normal blood glucose levels of a diabetic patient who has been immunised with glucagon antibodies.

PEST CONTROL

Attack on Rodents

from a Correspondent

RODENT pests are most effectively controlled with poisons. Such rodenticidal agents are hazardous, their biological actions are by no means specific for the target species, and their use presents a danger to both man and domestic animals. New approaches to the problem of rodent control, by chemosterilisation and genetic means, are discussed by Marsh and Howard in a recent issue of the *Bulletin of the World Health Organisation* (**48**, 309; 1973). Chemosterilisation has reached the experimental stage of development, whereas the genetic approach is still highly speculative.

The eventual application of both lines of attack will mean, except in instances where an immediate and complete disappearance of pests is required, a gradual and a biologically far sounder depletion of rodent populations than is possible with present methods of control. This steady and more natural dilution of a rodent population density may, depending on the situation, be advantageous, of no consequence or disadvantageous. In instances of rodent-borne diseases a steady decline in numbers would be advantageous; there would be no sudden appearance of disease vectors from poisoned rodents as would occur in the case of a sudden drop in numbers resulting from the use of rodenticides. In areas such as rangeland, crop-producing areas, sewers and warehouses, where complete eradication of pests is not necessary, chemosterilisation and genetic control measures will be entirely satisfactory. And in cases where use of the rapidly effective rodenticides is necessary, chemosterilisa-

tion and genetic measures will form an important means of consolidating such eradication and keeping at bay the incipient resurgence of the suppressed rodent population.

Chemosterilisation is a term broadly used to include direct effects (either permanent or temporary) on the fertility of either or both sexes, and indirect effects (through behavioural or physiological mechanisms) on the reproductive capacity of the population or on the fecundity of the offspring.

A number of compounds—chemicals that can be administered directly to the natural pest population in baits and tracking dusts—have been evaluated for use as potential chemosterilants. The practicability of using hormonal compounds in this manner to inhibit the development of embryos is reduced because such compounds have to be made available throughout the breeding season. Alkylating agents are currently showing greater potential for use as chemosterilants. These compounds possess a wider range of biological activity than hormones because they affect the fertility of both sexes at adult or progenitive stages. One of the most promising agents is 3-chloro-1,2-propanediol, a compound which creates permanent sterility in certain rodent species and causes temporary sterility in a rather wider variety of mammals. The specificity of such anti-fertility agents would minimise any risk to humans and domestic animals.

Means of effecting chemosterilisation indirectly are suggested by Marsh and Howard. These include inhibiting the production of sexual pheromones so upsetting normal reproductive behaviour, and increasing the fertility of rodent pests so overloading the population and causing it to crash (as occurs naturally in some species).

The genetic approach to rodent control is at present theoretical, and though feasible is, practically, far from simple. Genetical factors are required that will make the population inherently more susceptible to diseases, to predation, to intraspecific stresses, to imbalances in physiological and behavioural processes and to its own lethal genes. Such genetical traits, introduced into the natural population by the release of new breeding stock (reared in captivity), will be diluted out of the population unless they possess a selective advantage also. The frequency with which fresh breeding stock would need to be introduced into the natural populations remains to be determined. Genetical changes could be induced directly in the natural pest populations by exposure to suitable mutagenic compounds. These, however, would be shorter-acting and less specific than genetical control by inheritance.

Rodent control measures, when designed in accordance with these pro-

posals, will provide a benign means of attacking the problem of rodent pests as compared with the current use of poisons. One great advantage is that control will be highly selective, particularly in the case of genetic control where procedures can be aimed directly and specifically at a particular pest population. And in the case of the genetical approach the control measures may also be self-perpetuating.

NEUROCHEMISTRY

Strychnine Binding

from a Correspondent

STRYCHNINE is not perhaps the most subtle of drugs. Sensible persons would do better to inquire among the more obscure members of the South American Crotalidae or Elapidae for poisons acting with rather less striking manifestations.

Nevertheless strychnine, in spite of its shortcomings, has had a most distinguished scientific career in modern times as in old. Elucidation of its structure—one of the great classics of structural organic chemistry—was engineered 30 years ago by Robert Robinson. R. B. Woodward, in one of those thoroughbred total syntheses that appear from time to time out of Harvard, put together what Robinson called “for its size the most complex substance known”—he was biased but probably correct. The establishment of the absolute configuration by X-ray crystallography came in the mid nine-

teen fifties. Everything about strychnine seemed solved therefore, except precisely how it acts in the nervous system. But this seems to be a mystery no longer.

In the latest issue of the *Proceedings of the National Academy of Sciences* (70, 2832; 1973) Young and Snyder describe their use of tritiated strychnine to measure the binding of the poison to synaptic membranes. It has been known for many years that strychnine antagonises synaptic inhibition, especially in the spinal cord. Young and Snyder now report that one reasonable prerequisite for the effect can be demonstrated; that is to say, they have found a specific interaction of strychnine with synaptic membranes of rat spinal cord. Specific binding was about eight times greater in purified synaptosomal fractions or synaptic membranes than in the starting homogenate and was found to be saturable with half-maximal binding occurring at about 3×10^{-8} M. The rate of interaction of tritiated strychnine with purified synaptic membranes is remarkably fast: binding is maximal within a minute at 25° C and even at 4° C half maximal binding takes just 36 s. The rate of dissociation of the complex by excess cold strychnine is unmeasurable at 25° C: at 4° C the half life is estimated as about 30 s. The dissociation constant from these measures gives a high value of about 4×10^9 M for a single species of strychnine receptor.

Synaptic inhibition in spinal cord and brain stem (but not in cerebral cortex) is brought about by glycine, the simplest of amino acids. Glycine is a major inhibitory neurotransmitter in the cen-

Endonuclease Recognition Site Sequenced

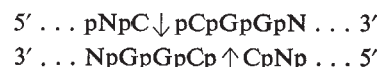
It seems certain that the process of bacterial restriction is mediated by endonucleases which recognise particular sequences in ‘foreign’ DNA. The sequences recognised by endonuclease R from *Haemophilus influenzae* and by endonuclease RI from *Escherichia coli* have been determined, and in *Nature New Biology* next Wednesday (December 5) Sugisaka and Takanami report the analysis of the sequence recognised by *Haemophilus aphrophilus* endonuclease (endo AP).

To demonstrate the specificity of the enzyme it was necessary to show that it degrades different DNAs in the same way. In these experiments T3 DNA and fd RFI (doubly closed replicative form) DNA were degraded with endo AP and sequence analysis of the 5′ and 3′ ends of the fragments gave identical results for both DNAs.

After degradation of the DNAs with endo AP the 5′ ends were labelled with 32 P using polynucleotide kinase (after alkaline phosphatase treatment). The sequence at all these 5′ ends was shown to be pCpGpGpN (N=A, G, C or T).

To determine the 3′ end of the fragments both DNAs were uniformly labelled with 32 P *in vivo* then digested with endo AP. Following hydrolysis with micrococcal nuclease the NpN fraction from the 3′ ends was analysed. The 3′ ends of these dinucleotides all had the sequence—pNpC.

Using the information on both the 3′ and 5′ terminal nucleotide sequences, the authors conclude that the sequence recognised by endo AP must be:



The arrows indicate the point of cleavage.

Endo AP cleaves the fd RFI DNA at thirteen sites yielding fragments of about 500 base pairs. If the base sequence is random the sequence CCGG would be expected to occur once in every 625 nucleotide pairs. It therefore seems likely that the sequence of tetranucleotide pairs contains enough information to account for the observed degree of specificity.

tral nervous system and strychnine antagonises the hyperpolarising effects of glycine at spinal synapses. One plausible mechanism for the antagonism turns out to be correct; strychnine and glycine compete for the same synaptosomal binding sites. This is shown by dissociation of the tritiated strychnine-synaptic membrane complex by a large excess of cold glycine. The affinity of glycine for the specific receptors is three orders less than that of strychnine which fits in with the neurophysiological evidence for the dominance of strychnine over glycine.

Another piece of evidence supporting this contention is the almost identical regional distribution of endogenous glycine levels in the central nervous system—low in brain, medium in brain stem and highest in spinal cord, with the increasing capacity of synaptosomal fractions obtained from these regions to bind strychnine. It should therefore now be possible to pull out and identify the membrane components responsible for strychnine binding in the central nervous system and to compare these with the high affinity sites responsible for glycine uptake in nerve terminals that seem not to bind to strychnine.

MOOSE

Sodium Requirements

from our Plant Ecology Correspondent

SODIUM is an element which is required in far greater proportions by animals than by plants; in general plants tend to accumulate potassium from their environment rather than sodium. Since herbivorous animals rely on plants to a considerable extent for their ionic requirements, it is possible that in certain circumstances vegetation will fail to meet the sodium requirement of its herbivore predators.

This is precisely the situation which is described by Botkin, Jordan, Dominiski, Lowendorf and Hutchinson (*Proc. natn. Acad. Sci. U.S.A.*, **70**, 2745; 1973) on the Isle Royale National Park, Lake Superior, Canada. In this isolated and undisturbed ecosystem, an equilibrium exists between the vegetation, the moose population and their predators the wolves. It is estimated that 1,000–1,200 moose occupy the 550 km² of mixed conifer and deciduous forest of the Isle Royale Park, but in spite of this very high population density there is no evidence of sodium deficiency among the animals. This is surprising, since the bulk of the food of the moose consists of the current year's growth of leaves and twigs of woody plants, which are shown by Botkin *et al.* to contain little sodium.

An annual total of 170 kg of sodium in the material suitable for moose consumption in Isle Royale was estimated,

assuming a concentration of 10 p.p.m. within the browsed material. This assumption is not unreasonable; for example, determinations for sodium concentration in leaves gave *Abies* 2.8 p.p.m., *Betula* 15.8 p.p.m. and *Populus* 7 p.p.m. Allowing for the fact that only 10–20% of the available browse is removed, the total sodium input from this source into the moose population is 17–34 kg yr⁻¹. But it would seem, from calculations of the sodium content of new tissues minus sodium losses from the urine and faeces of the moose, that the population in Isle Royale has an intake of 243 kg yr⁻¹. The browsing of moose, which represents 90% of the animals' annual food intake, thus supplies only 7–14% of its annual requirement for sodium.

The question arising from these data is where do the moose obtain the balance of this requirement? One possibility is that the animals derive their sodium from the mud licks which they are known to use, but this is unlikely because these licks contain concentrations of only about 24 p.p.m. sodium, a value only twice as great as most of the leaf material.

During a period of about 8 weeks in the summer, moose feed extensively on aquatic plants which were found to contain very high concentrations of sodium; for example, some of the determinations by Botkin *et al.* were *Calla palustris* 1,713 p.p.m. of sodium, *Carex rostrata* 246 p.p.m., *Myriophyllum* 4,750 p.p.m. and *Utricularia* 8,048 p.p.m. These values are between twenty and eighty times greater than those obtained for terrestrial vegetation, and are greater in floating and submerged aquatics than in emergent species.

Calculations from the productivity of these aquatics show that some 2,500 kg sodium—ten times the annual requirement of the herd—is available for moose consumption each year in the park. Although this may account for the overall annual sodium budget, it does assume some mechanism for sodium retention in the moose during the 10 months of the year when sodium is scarce. The authors suggest that potassium may be substituted for sodium in certain circumstances, for example in parotid secretions, which would result in sodium conservation.

MICROEARTHQUAKES

Earth Tide Trigger

from our Geomagnetism Correspondent

ALTHOUGH there have been many attempts to show that tectonic and volcanic activity can be triggered by other much smaller forces, few have been entirely convincing. Moreover, this is a field in which apparently valid claims to have detected correlations are

often shot down shortly after by equally, if not more, convincing explanations of the same data. One therefore tends to approach such claims warily, holding back any jubilation until other workers with similar interests have had time to make up their own minds. Having said that, however, there certainly seems to be something in a demonstration by Mauk and Kienle (*Science*, N.Y., **182**, 387; 1973) that certain microearthquakes in Alaska are triggered by Earth tides.

This is not the first time that Earth tides have been proposed as trigger forces, although again there is a long record of failure to produce convincing evidence. Mauk and Kienle believe that the correlation between microearthquakes in an aftershock sequence and the principal diurnal tidal component, found by Ryall *et al.* (*Bull. seism. Soc. Am.*, **58**, 215; 1968), may be the one success as far as earthquakes are concerned; and Johnston and Mauk (*Nature*, **239**, 266; 1972) have reported a "definite" correlation between the eruption periodicity of Stromboli and the fortnightly tidal component. But apart from these and one or two other possible correlations involving volcanic activity there is very little else—a general failure which Mauk and Kienle think reflects not that Earth tides cannot act as trigger forces, but rather that, if they are to do so, three strict conditions must be satisfied.

The first of these is that the level of tectonic stress in the area must be high enough initially, and that the rate of accumulation of tectonic stress must be "sufficiently smaller than the periodicity of the tides", for the small-amplitude tidal perturbations to have an effect. Second, events must be closely grouped in space for there to be the chance of having a spatially homogeneous mechanism able to respond to the perturbations and thus trigger each event in a similar way. And, finally, events must be shallow enough to lie in regions where brittle fracture of the rock is important.

Each of these conditions is thought to apply to both aftershock zones and volcanic regions, and thus particularly to St Augustine volcano which has been investigated by Mauk and Kienle. St Augustine, which lies at the mouth of Cook Inlet in the Aleutian Islands, is an active composite volcano comprising an alternating series of outward-dipping pyroclastics and andesitic and dacitic lava flows and a central endogenous lava dome. Seismic monitoring since 1970 has indicated considerable microearthquake swarm activity during which the number of events per day may rise two or three orders of magnitude above the background level. That the shocks have extremely shallow foci is shown, first, by the determinations of focal positions; and Mauk and Kienle suggest

that the origin of the events may be related to deformation and fracturing occurring during periods of rapid growth of the central volcanic cone. Moreover, with one exception, for which $b = 1.35$, the b values for the eight swarms analysed ranged from 1.7 to 2.5. This again supports the idea that the events are shallow in that Minakami (*Bull. Earthq. Res. Inst.*, **38**, 497; 1960) has shown that high (2–3) b values arise from earthquake swarms originating at depths of generally less than 1 km. In addition, shallow origins of the shocks may be deduced from the body wave attenuation patterns.

Plots of the hourly frequency of the microearthquakes generally show a diurnal peaking of activity which, for the seven high b value swarms, correlates visually with peaks in the calculated magnitude of the total tidal vector. Two distinct phase relationships were observed, however, each occurring with roughly the same frequency. The slightly more frequent phase relationship involved no obvious phase shift between the earthquake activity peaks and the corresponding tidal vector peaks when observed visually, although detailed statistical analysis more accurately indicated a phase shift of about one hour with the peak microearthquake activity lagging the tidal peaks. The slightly less frequent phase relationship involved a visual lag of 5–6 h (about 5 h from detailed analysis) for the microearthquake activity. As far as the one low b value swarm was concerned, no visual correlation was apparent. Detailed statistical correlation showed, however, that the phase lag of 1 h was present here also, albeit with a higher standard deviation than for the other swarms.

The swarms investigated occurred during 1971 either before or after the volcanic eruption of October 7, 1971, but no differences in the temporal variations between pre-eruption or post-eruption swarms were observed. This suggests that the discovered phase relationships were independent of the stress condition of the volcano which was presumably changed by the eruption. The phase delay of 5 h does correlate with the maximum oceanic tidal loading. Mauk and Kienle thus suggest that the microearthquake activity lagging by 1 h is the result of direct triggering by tidal stresses and that the activity lagging by 5 h is related to the time of maximum oceanic tidal loading.

QUASARS

Nature of Redshifts

from a Correspondent

PLAGEMANN of Dunsink Observatory, Dublin, claims to prove (*Mon. Not. Roy. astr. Soc.*, **164**, 303; 1973) that the

quasars with compact radio sources and flat radio spectra are distributed anisotropically on the sky. If true this would be a significant result, casting doubt on the cosmological nature of the redshifts of these objects because if the microwave background radiation is, as most astronomers believe, cosmic black-body radiation left over from the fireball, then its extreme isotropy makes it improbable that the distribution of matter can show any very severe anisotropy on the large scale. Moreover, Plagemann's claimed anisotropy takes the form of a correlation with the Local Supercluster, a disk-like concentration of bright, nearby galaxies apparently centred on the Virgo cluster. This could only mean that these quasars are very nearby indeed, within about 30 Mpc.

It is perhaps surprising that the question of the true distances of the quasars has remained a matter of controversy

for so long. The trouble is that although some of the reported phenomena raising doubt have been laid to rest, others have turned up to keep the publications flowing. Little is heard now of Arp's pairs of radio sources on either side of peculiar galaxies, or of Burbidge's anomalous concentration of quasar redshifts around a value of 1.95. And three lines of work have pointed to at least some quasars with genuinely cosmological redshifts: the association of several quasars with small redshift with groups of galaxies with the same redshift, the inverse correlation of apparent radio size with redshift for the more extended quasars, and the existence of fuzziness round some small redshift quasars suggesting an underlying normal galaxy.

But like snakes from the head of the Medusa, new problems spring up to replace those already slain. The announcements last week in *Nature* by

Curious Behaviour of Carbon Fibres

FINE fibres of highly graphitised carbon have excited much interest because they are strong, stiff and light. The high strength and stiffness both stem from the strong c-c bonds in the graphite layer planes and, since the interlayer bonds are much weaker, the graphite lattice has of necessity a large anisotropy of both strength and stiffness. Accordingly, the mechanical properties of carbon fibre must vary with the degree of graphitisation of the lattice (a 'glassy' disordered arrangement of carbon atoms implies a comparatively weak 'average bond') and with the degree and nature of preferential alignment of the graphite layer planes where these are well developed. When, in addition, the quality and degree of alignment of graphite layers are also a function of position in the fibre cross section, the number of structural variables that affects mechanical properties becomes quite disconcerting.

Evidence has in fact accumulated that carbon fibres made according to the British process by pyrolysis of polyacrylonitrile have a duplex structure with a poorly graphitised core of low stiffness surrounded by a highly graphitised and aligned sheath of high stiffness. If, as seems likely, the sheath is of fixed thickness, then a reduction of the total fibre diameter will increase the proportion of sheath material and so raise the overall Young's modulus. Such dependence of modulus on diameter has been established, and the sheath/core hypothesis was advanced to explain this dependence.

In *Nature Physical Science* next Monday (December 3), Hart and Pritchard of Kingston Polytechnic confirm the

diameter dependence of modulus, and report on an attempt to test the sheath-and-core hypothesis more directly. Fibres originally pyrolysed at several different temperatures were submitted to attack by nitrogen dioxide at temperatures up to 925 K, using different pressures and periods of attack. Fibre diameters were reduced by as much as 80%. For fibres originally pyrolysed at 1,750° C, increases of modulus of up to 80% were established as the fibre diameter decreased; the amount of modulus increase depended on the conditions of attack, especially time and temperature. Fibres pyrolysed at 1,350° C showed negligible modulus changes in spite of thinning, and fibres pyrolysed at 2,750° C appeared resistant to attack.

The apparent paradox that removal of a stiff sheath leads to modulus increase is dealt with by the authors by the postulate that the attacking gas penetrates capillary pores in the sheath and preferentially attacks the poorly graphitised core. In the process, they believe that the sheath collapses onto the hollow core region and, in so doing, undergoes reformation of the graphite structure with the formation of new bonds. They believe that the inefficacy of low attack temperatures in increasing modulus is consistent with their postulate. It is not altogether clear whether the modulus increase is taken to be due to increased perfection of graphite structure, or increased alignment produced during the gas attack. The authors very properly conclude by pointing to the need for high-resolution electron microscopy to test their interesting ideas.

Wampler *et al.* (246, 203; 1973) of a pair of quasars a few seconds of arc apart but with very different redshifts, and by Hazard *et al.* (246, 205; 1973) of several examples of quasars apparently in clusters of galaxies but with much larger redshifts than the cluster could have, must raise doubts in the minds of all but the most diehard cosmological redshifters (by no means a rare species).

Not so long ago Karlsson (*Nature phys. Sci.*, 245, 68; 1973) was suggesting that the regular peaks in the distribution of quasar redshifts (Burbidge's 'periodicity') were absent from the quasars with extended radio sources, but present for the compact quasars. Unfortunately this was not established at a very significant level statistically.

This is again true for Plagemann's claim of anisotropy on the sky of compact quasars. When one works through his paper, past Fisher's method of statistical analysis of dispersion on a sphere, Monte Carlo computer algorithms, and topological considerations, it turns out that Plagemann's complete sample of compact quasars has only seven objects in it, and that the anisotropy disappears if three quasars at low galactic latitude have failed to be identified.

Clearly nobody is going to be moved from their favourite theory of quasar distances by that kind of statistics, or indeed by any kind of statistics. What is needed (as Wampler *et al.* point out) are good examples of associations of quasars and galaxies with different redshifts and signs of interaction. It is too much to hope to see a galaxy flare up, become a quasar, and change its redshift.

NUCLEAR STRUCTURE

New Giant Resonances

from our Nuclear Theory Correspondent

One of the most interesting events in recent years has been the discovery of new giant resonances in nuclei. The broad maxima in many reaction cross-sections around 20 MeV for light nuclei and at progressively smaller energies for heavier nuclei have long been known and are interpreted as E1 dipole resonances. They have been analysed microscopically as a coherent superposition of particle-hole excitations and more physically as the oscillation of the protons and neutrons in the nucleus against each other.

Enhanced cross sections have now been found at higher energies, and these are interpreted as giant multiple resonances of higher order. These resonances can be excited by inelastic proton scattering, and a particularly striking example has recently been analysed by Geramb, Sprickman and

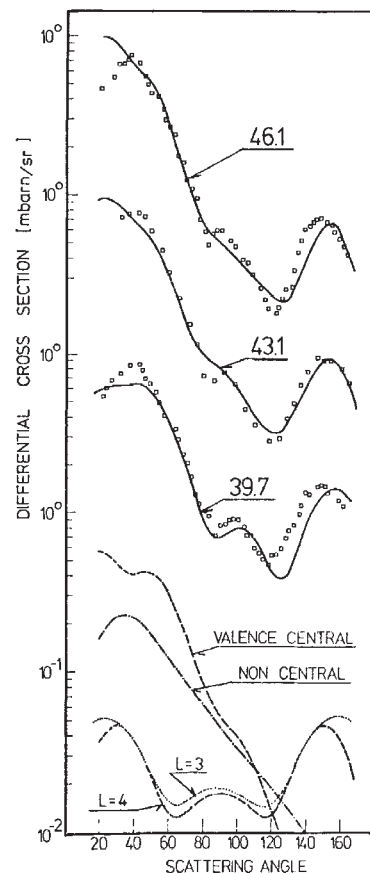
Strobel (*Nucl. Phys.*, A199, 545; 1973). They examined the differential cross sections for the $^{16}\text{O}(p,p')^{16}\text{O}$ reaction to the $J^\pi=2^-$ state at 8.88 MeV for proton energies from 23 to 46 MeV. Such cross sections are usually analysed by the microscopic distorted wave theory using an effective interaction consisting of central, spin and isospin-dependent and tensor components. Such a calculation gives a good account of the forward cross section but falls rapidly in the backward direction and completely fails to account for the prominent peaks found experimentally. This indicates that another mechanism is contributing to the reaction.

The forward peaks that are well understood by the direct distorted wave theory are inhibited in reactions involving a parity change compared with those involving no parity change. The backward peaks are thus more prominent in parity-change reactions, so these provide a better test of models devised to account for them. In the $^{16}\text{O}(p,p')^{16}\text{O}$ to the 2^- , 8.88 MeV state the conservation of angular momentum and parity require $S=1$ spin flip and parity change, implying a spin-dependent interaction or an exchange contribution.

The mechanism proposed is the excitation of a multipole giant resonance by the incident particle followed by decay of the resonance by proton emission. The nucleons remaining after emission combine with the proton initially responsible for exciting the resonance to give the final excited nuclear state. This process is called the core polarisation exchange mechanism. It is an exchange process because the emitted nucleon is not the same as the incident nucleon, as it is in direct processes. The direct core polarisation mechanism makes no contribution to the transitions involving a change of parity.

The cross section for this mechanism was calculated by the antisymmetrised distorted wave theory. The ground state of ^{16}O is a doubly closed shell, and the 2^- , 8.88 MeV state is represented by linear combination of particle-hole excitations. The incident and outgoing particles are represented by distorted waves generated by a complex optical model potential with spin-orbit coupling. The particle-core interaction is restricted to exchange contributions with isospins for the intermediate resonance states of $T=0$ or 1.

The data from 23 to 46 MeV were analysed assuming a direct contribution plus a core polarisation exchange contribution, and the amplitudes and energies of the giant resonance contributions were adjusted to optimise the fit to the inelastic scattering data. It was found that a good overall fit is obtained with giant quadrupole ($L=2$), octupole ($L=3$) and hexadecupole ($L=4$) resonances at 24, 35 and 42 MeV respec-



Differential cross sections for the $^{16}\text{O}(p,p')^{16}\text{O}^*(2^-, 8.88 \text{ MeV})$ reaction at 39.7, 43.1 and 46.1 MeV compared with distorted wave calculations including the $L=3$ and $L=4$ giant resonances. Also shown are the separate contributions of each reaction mechanism.

tively, in addition to the familiar dipole ($L=1$) resonance at 22 MeV.

The experimental differential cross sections for the $^{16}\text{O}(p,p')^{16}\text{O}$ (2^+ , 8.88 MeV) reaction at 39.7, 43.1 and 46.1 MeV are compared with the calculations in the figure. Also in the figure are shown the contributions of the valence central and non-central interactions, which together account very well for the forward cross sections but not at all for the backward. In this energy range only the $L=3$ and $L=4$ giant resonances contribute appreciably, and as shown in the figure they are able to account very well for the backward peak in the experimental cross sections.

These higher order resonances have been found in several other reactions and in particular the $(p,2p)$ reaction seems to provide a promising way of exciting them. These resonances have widths of several MeV, so they are not so easy to study as narrower ones; it is therefore desirable that they should be excited in as many ways as possible to ensure that all the data are consistent with the interpretation. It is likely that such data will soon be forthcoming and will enable thorough studies to be made of these new modes of nuclear excitation.

Science in Australasia



Sydney Opera House [Australian Information Service]

IN the following pages a few of those closely concerned review some of the science being done in Australia and New Zealand and look at the way in which the two countries support their scientists. There is one aspect of Australasian science, however, which deserves some comment but which can only be a matter of personal opinion.

In 1836 Charles Darwin wrote of New Zealand: "I believe we were all glad to leave; it is not a pleasant place and the greater part of the English there are the very refuse of Society"; and of Australia: "Farewell, you are a rising infant and doubtless some day will reign a great princess, but you are too great and ambitious for affection, yet not great enough for respect." Australasians have always been sensitive to the attention they receive from the rest of the world, particularly from the Europe-North America axis, and are keen to know whether they are now regarded with affection and respect and deemed to live in a pleasant place.

This concern has very realistic roots for scientists. Australasia is not a natural break in anyone's journey. It is not widely known either for unusually generous financial support of its scientists or for academic cloisters steeped in tradition. Journals arrive late, preprints are harder to come by and telephone calls to co-workers are not the casual affairs they can be elsewhere. There are thus reasons why scientists may not think seriously of ever visiting the area, let alone working there.

To this geographical isolation one has had to add a degree of self-cultivated philistinism amongst Australians. (Hereafter we speak of Australia rather than Australasia because of a more limited knowledge of New Zealand.) A. J. Marshall described their principal pastimes at the time of Darwin's visit as rum, horse racing and cricket, and it is a common belief beyond Australian shores that the same is still true. Australians are said to suffer from 'cultural cringe'—a desire to appear like sophisticated Europeans coupled with an obsessive fear of putting a foot wrong. The Australian image—and outsiders often tend to treat the country as a phenomenon rather than an equal—should not be underestimated as an inhibitor of a free flow of scientists every bit as powerful as the geographical

isolation. It is no accident that a majority of scientists live within reach of the cultural centres of the Northern Hemisphere.

All this is changing rapidly. Obviously the Sydney Opera House can be only a symbol, but by the same token the South Bank in London was also a symbol which has played a large part in the English cultural renaissance. Good news is heard on many fronts; there are new theatres and concert halls in Perth, Brisbane, Adelaide and Sydney. After many years in which Australian artists, writers and composers left their country to receive recognition, there now appears to be a reversal of the flow. The Australian Council for the Arts has been reorganised to allow professionals rather than rich dilettantes to run the show. It would be wrong to give Mr Whitlam's one-year-old government too much credit for all this; rather, the feeling in the country in favour of cultural change was also one in favour of political change.

If Australians are now making their country more appealing it is also the responsibility of outsiders to help break down the geographical isolation. The scientific community means little if communication between London, Boston and San Francisco is at the expense of that to Tokyo, Calcutta and Canberra. Science, even more than the post office and the airlines, needs more communal activity.

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Funding and Control of Australian Science

R. N. ROBERTSON

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Sir Rutherford Robertson discusses how the Australian science effort is organised and financed, and describes how the present government is approaching some of the problems.

AUSTRALIA, a federation of six independent states, each with its own parliament and civil service, as well as the federal parliament and civil service, has more complications in the administration and funding of science than many other countries. For example, since defence is a federal responsibility, all related scientific work is under the control of the Australian (also known as Commonwealth or Federal) government; by contrast, the states have substantial responsibilities for the administration of agriculture and fisheries and many scientists concerned with these activities are employed by the states, some of which have strong departments of agriculture. However, the federal government is the source of more than half the money which is spent on research and development. Analysis of the policies for research and development in Australia is further complicated at present because the Labor government which, under Prime Minister Whitlam, was elected in December 1972, has not completed plans for implementing its policies, some of which will have a considerable effect on science.

As in many countries in recent years, the increasing demands for research for community welfare, for health, for primary and secondary industry and so on, have resulted in constant discussion of the amounts that should be allocated both in total and for specific purposes. It was soon apparent that detailed knowledge is lacking of existing expenditures on science by the different agencies—federal, state, university, private institutions and industry—largely on account of the difficulty of dissecting amounts spent on science from total expenditure. The Department of Education and Science, established in 1967, planned to remedy this deficiency with a detailed study of the research and development expenditure in the fiscal year 1968–69 (Survey and Comparisons of Research Expenditures, known as Project SCORE)¹. The form of the survey is similar to, but not identical with, those conducted in other countries by the Organisation for Economic Cooperation and Development (OECD). This survey is not yet complete, but a private communication from the Department of Science provided the following information:

In 1968–69 the total expenditure on research and development by Australia was \$A342 million, of which \$A8 million was for work carried out overseas. Of the \$A334 million spent in Australia, 92% was incurred in the natural sciences and the remainder in the social sciences. Government plays a major role in both the funding and performance of research and development in Australia. Thus in 1968–69, the federal and state governments collectively contributed two-thirds of the funds, and research and development carried out in government agencies accounted for about half of the gross

expenditure. In contrast, the business enterprise sector contributed about one-quarter of the funds and accounted for about one-quarter of the expenditure on research and development² (see Fig. 1).

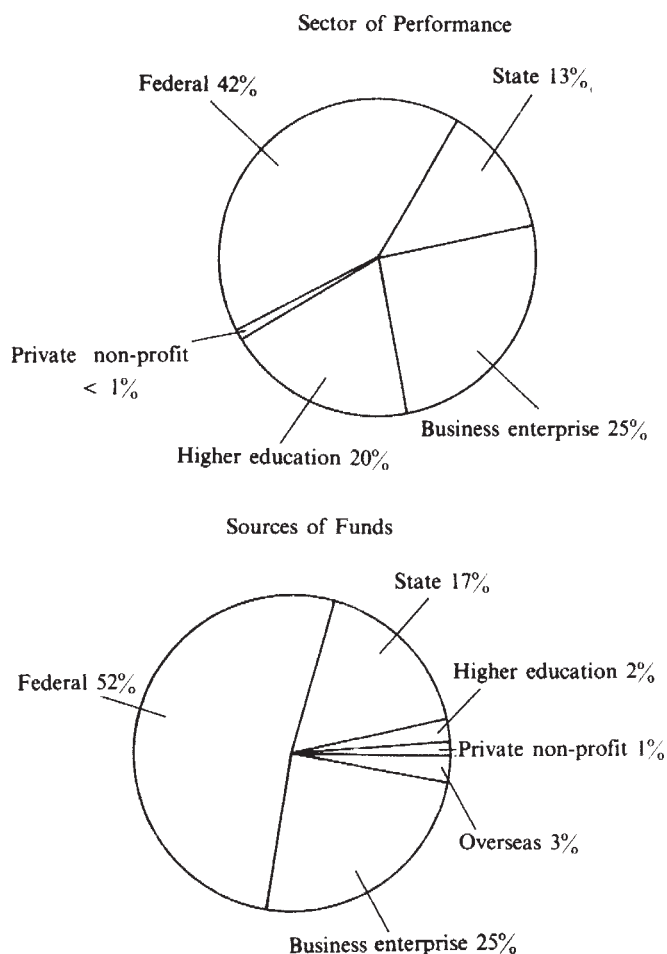


Fig. 1 Gross expenditure on research and development by sector of performance and source of funds.

The figures for 1968–69 expenditure on research and development in the university, state government and other non-profit sectors have not yet been published. The Department of Science advises that the university expenditure was \$A66 million (some from government grants) and state government expenditure was \$A42 million. The total expenditures are shown in Table 1.

Precise data are not available for Australia's present expenditure on research and development. An extrapolation based on the SCORE survey for 1968–69 indicates that current expenditure on research and development in the natural sciences, within Australia, lies between 1.0 and 1.1% of the gross national product, that is, between about \$A400 million and

Table 1 Expenditure on Research and Development* in Australia in 1968-69 (Irrespective of the Source of the Funds)

Sector of performance	Expenditure (\$A million)	Proportion (%)
Federal government	139	41.6
State governments	42	12.6
Higher education	66	19.8
Business enterprise	85	25.4
Private non-profit	2	0.6
Total	334	100

*In the natural and the social sciences

\$A1 = £0.62 = \$US1.49

\$A450 million per annum. Since 1968-69 there is reason to believe that private industry's share of the gross national expenditure on research and development has increased.

Government Science

The largest single group of scientists in Australia is the Commonwealth Scientific and Industrial Research Organisation (CSIRO), a statutory body responsible directly to the Minister for Science. In a total staff of about 6,000, over 2,000 are professional scientists, about half of whom have qualifications of PhD or higher. Research within the CSIRO is concerned with both primary and secondary industry, with standardisation of scientific apparatus and instruments (the National Standards Laboratory is part of the CSIRO), with collection and dissemination of scientific and technical information and with the publication of reports and periodicals. These research activities are organised into thirty-six divisions with some additional units and sections. Some divisions are directed to the needs of a particular industry; others are more specifically concerned with a single discipline. The budget of the CSIRO for 1972-73 was \$A77.7 million³. The approved estimates⁴ for 1973-74 are \$A93.6 million, of which \$A79.2 million will come directly from the Federal Treasury and \$A14.4 million will come from contributory funds which include such sources as the Wool Research Trust Fund, Meat Research Trust Account, Wheat Research Trust Account and so on, many of which are made up of compulsory contributions from the industries supplemented by government grants.

The CSIRO is administered by an executive consisting of five full-time and four part-time members. All the present members except one have scientific training and the present chairman is Dr J. R. Price, a well known organic chemist. The organisation has been a very successful body which, over the years, has established an environment for research that enables it to employ first class scientists who make a substantial contribution to solving national and industrial problems. The organisation is, however, constantly reviewing its responsibilities and its programmes. In releasing the 1972-73 report, the chairman spoke of the way in which, during the past year, the CSIRO has broadened its traditional research goals to take account of rapidly changing community needs, a development which calls for closer collaboration with social science, mainly with the social scientists in the universities. When tabling the report in parliament, the Minister for Science expressed his intention "to see that the research work carried out by the CSIRO continues to be 'people oriented'".

The next largest group of scientists is concerned with defence research. Of the money spent on research and development by the federal government in 1968-69, approximately \$A57 million¹ was spent in this way, most being spread over four major defence research establishments of the Department of Supply, namely, the Weapons Research Establishment (principally guided weapons and applied physics, including electronics; Woomera test range for joint

Australian-British interests); Defence Standards Laboratories (principally research into defence materials; operates Joint Tropical Research Unit in conjunction with British authorities); Aeronautical Research Laboratories (principally aeronautics); and Central Studies Establishment (operational research).

Approximately 6,500 man-years of effort were devoted to this programme in 1968-69, of which about 20% was carried out by professionally qualified scientists or engineers. Broad policy for defence research and development is in the hands of the Chief Defence Scientist. Advice to the minister is provided by the Defence Research and Development Policy Committee, chaired by the Chief Defence Scientist, and by the Defence Science Board, chaired by the Secretary, Department of Defence.

The Atomic Energy Commission, which was established in 1953, has wide responsibilities including, in addition to research, advice to the government on uranium exploration and use, construction and operation of generating plant, and making grants-in-aid to research. The commission spent \$A13.8 million in 1972-73 and has approved estimates of \$A14.9 million in 1973-74 (ref. 4). The total staff is approximately 1,130, of whom 300 are professional scientists operating in eight divisions. Active cooperation with universities is achieved through the Australian Institute of Nuclear Science and Engineering, of which each university is a member. The Atomic Energy Commission is a statutory body, reporting to the Minister for Minerals and Energy, and governed by a commission of five, two full-time and three part-time.

Other federal government bodies concerned with science include the Post Office, the Bureau of Mineral Resources of the Department of Minerals and Energy, the Bureau of Meteorology and the Antarctic Research Division of the Department of Science, and the Commonwealth Serum Laboratories, National Biological Standards Laboratory and Australian Radiation Laboratory of the Ministry of Health.

Departments concerned with science in the different states mainly carry out research and development for the agricultural and pastoral industries, for fisheries and for forestry but, in recent years, substantial contributions have been made by departments engaged in research and development support for secondary industry and other activities.

Science in Universities

The Australian Universities Commission advises the Australian government on the financial assistance for the maintenance and development of the Australian universities in each triennium. Up to the present, the support has come from both federal and state governments. Thus in the current (1973-75) triennium, 46% of the total income came from the federal government, 35% from the states, 11% from fees and 10% from miscellaneous sources, including endowments⁵. The Australian government has announced its intention to abolish all fees from 1974 so dependence on federal government funds will increase. Funds earmarked for university research (about half those estimated as spent on research in universities) are from four main sources: (a) general recurrent funds recommended by the commission, about 22.2% in 1970; (b) special grants for research recommended by the commission, about 11.6%; (c) grants from other government sources, particularly the Australian Research Grants Committee and the National Health and Medical Research Council, about 44.9% from federal and 2.1% from state grants; (d) other grants, contracts and donations from private sources, about 19.3%. As might be expected, most of the research funds (35.5%) were devoted to science faculties, 19.0% to medical faculties, 14.4% to engineering, 12.9% to agriculture and 3.4% to veterinary

science—a total of 85.2% to the natural science-based faculties. The remaining funds came mainly from general university grants which are financed mostly by government.

The Australian Research Grants Committee, established in 1965, has consistently “sought to direct itself to supporting the most outstanding and promising research being carried out in Universities and research institutions”⁶. The committee invites submissions from individuals or teams and bases its selection on reports from referees and assessors.

The funds distributed by this committee, not confined to science, amounted to 19.6% of the funds earmarked for research in universities in 1970 (ref. 5). Approximately 13% of the Research Grants Committee allocations went to the humanities and social sciences, another 13% to the engineering and applied sciences and the remaining 74% to the physical, chemical, biological and earth sciences.

Medical research in universities is partly supported by the National Health and Medical Research Council which distributes grants for research on the advice of its subcommittee, the Medical Research Advisory Committee. In 1968–69, the year of the SCORE survey, it distributed \$A1.6 million, two thirds of which was for university research.

Research in Industry

Of the \$A198 million spent on research and development by the federal government in 1968–69, \$A9 million or 5% went to the business enterprise sector (private communication from the Department of Science). In 1967, the federal government established the Industrial Research and Development Grants Scheme, which is administered by a board that now reports to the Minister for Secondary Industry. In the first four years of its existence, the board distributed \$A44 million to firms which had, themselves, spent about \$A200 million⁷ in the same period on increased research and development mostly within the companies, though some was spent on contract research. Companies supported in this way cover a wide range as regards both size and products (such diverse things as building materials, food and electrical equipment). Of the 500 or so companies so far assisted, nearly half had previously carried out no research; moreover the professional level of the employed research personnel has risen markedly overall since the scheme started. These developments have, in some measure, countered the criticism, often heard a few years ago, that Australian firms were dependent on overseas industrial research ‘know-how’. The smaller firms in Australia often regarded themselves as unable to support a research department and some of the larger firms, subsidiaries of still larger overseas companies, drew on the research expertise of the parent company in Britain, Europe or the United States. Some international companies which started research departments in Australia have closed them in periods of economic recession, giving rise to some alarm about the possibility of not having adequate industrial research teams in this country; the activities of the Industrial Research and Development Grants Board are important in ensuring that industrial research is increased and maintained.

Independent Research Institutions

There are a few independent research institutions in Australia, the most famous of which is the Walter and Eliza Hall Institute of Medical Research; other well known institutions are the Australian Mineral Development Laboratories and UNISEARCH, the contract research company sponsored

by the University of New South Wales. There are no research bodies with sufficient endowments to provide the full funding for the institution and most draw heavily on federal and state granting bodies. Several private foundations such as the Potter Foundation, the Myer Foundation, and the Ramaciotti Foundation for medical research, also support scientific work with grants. The museums, at least one in each state, are supported primarily by state government money.

Policy for Science

During the past decade there has been an increasing demand for a science policy machinery in Australia; the problems have been reviewed in an important article by Peres⁸, to be published shortly. The present government, while in opposition, had recognised, in 1965, a need for a comprehensive national approach to science. In 1968, the Science and Industry Forum of the Australian Academy of Science⁹ recommended the establishment of an independent Advisory Committee on Science and Technology. After some delay the Liberal government, then in power, established such a committee which held its first meeting in October, 1972; it was disbanded not long after the present government came into power in December 1972. The Minister for Science has stated that he intends to set up a Science Council with advisory powers, and an announcement is expected soon.

Meanwhile the minister (W. L. Morrison) announced to the media on October 21 that he had asked the OECD to carry out a wide ranging examination, early next year, of Australia's scientific and technological activities. It is suggested that the way in which Australia uses science should be analysed and a coordinated plan developed. The two or three member panel appointed by the OECD will visit Australia in March or April next. This is part of the government's plan to see more of the efforts of Australian scientists and technologists being turned, in future, to social and environmental problems. The results of such a survey and the policy which the government intends to adopt, particularly in relation to review and control of scientific expenditure, will be awaited with great interest.

I thank the officers of the Australian Government Department of Science for their assistance in providing the data referred to in this article.

¹ Department of Education and Science, *Project SCORE: Survey and Comparisons of Research Expenditure. Report 1. Research and Development Expenditure by the Commonwealth Government 1968–69* (Australian Government Publishing Service, Canberra, 1972).

² Department of Trade and Industry, *Survey of Industry Research and Development Expenditure in Australia 1968–69* (Australian Government Publishing Service, Canberra, 1972).

³ Commonwealth Scientific and Industrial Research Organization, *CSIRO Twenty-fourth Annual Report 1972–73* (CSIRO, Melbourne, 1973).

⁴ Parliament of the Commonwealth of Australia, *Estimates of Receipts and Summary of Estimated Expenditure for the year ending June 30, 1974* (Parliamentary Paper, Canberra, 1973).

⁵ Australian Universities Commission, *Fifth Annual Report* (Australian Government Publishing Service, Canberra, 1972).

⁶ Australian Research Grants Committee, *Report 1970–72* (Australian Government Publishing Service, 1972).

⁷ Australian Industrial Research and Development Grants Board, *Fifth Annual Report 1971–72* (Australian Government Publishing Service, Canberra, 1972).

⁸ Peres, L., *Science and Technology in Public Policy in Australia* (edit. by Forward, R.) (Cheshire, Melbourne, in the press).

⁹ Science and Industry Forum, Australian Academy of Science, *Science Policy Machinery for Australia* (Australian Academy of Science, Canberra, 1968).

New Zealand's National Research Advisory Council and the Use of Scientific Resources

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The role of New Zealand's 10-year-old National Research Advisory Council has been chiefly to advise the Minister of Science on the research activities of government agencies with particular reference to the total expenditure and priorities for expansion in various fields of application of science. In this article its chairman reviews the functions of the council and its achievements, and outlines future developments. Particular importance is attached to closer integration of the research carried out by government agencies, the universities, research associations and industry.

SUCCESSFUL application of scientific and technological knowledge to New Zealand's problems requires, as in other countries, not only human, financial and material resources, but an institutional framework providing the mechanism for coordinating national policy-making. In New Zealand, decisions on national scientific policies are made by the Minister of Science and the Cabinet, subject to the guidance and control of parliament during annual consideration of the Estimates. Scientific research programmes are planned and carried out in the various research divisions of government departments, in the universities and in the research associations and other scientific institutions. Advising the government on a coordinated national policy for scientific research which takes into consideration the work of all these agencies is the role of the National Research Advisory Council (NRAC).

Council's Form and Functions

The NRAC is directly responsible to the government through the Minister of Science. Its comprehensive functions, as defined in the Act which set it up in 1963, are to advise the minister on the promotion, development, planning and coordination of scientific research and services in New Zealand. In most countries today, governmental science policies are concerned with all scientific and technological activities, ranging from basic research to the practical application of new knowledge. The 1971 United Nations World Plan of Action for the Application of Science and Technology to Development emphasised the need for national science policy-makers to be responsible for all matters where science and government meet. The NRAC's terms of reference are wide enough to allow it to fulfil such a role.

The council consists of nine members. One of six who are appointed by the Governor-General on the recommendation of the Minister of Science is appointed chairman. The other three are the permanent heads of the Ministry of Agriculture and Fisheries, the Department of Scientific and Industrial

Research, and the Treasury. The present appointed members include four company directors, a university professor and a farm manager.

Members of the council broadly represent the scientific and technological community in New Zealand, but they cannot be expected to have the expertise or time needed to investigate every problem that comes before them. The council is therefore assisted by three standing advisory committees covering primary production, manufacturing and processing, and research related to the natural and social environment. Members of the council act as chairmen of these committees.

The council is an advisory body only. Its role is not to centralise and administer national scientific effort, but rather to coordinate and continuously to evaluate its effectiveness. The Act requires the council to determine priorities among the research activities of the various government departments, having regard to research done by other organisations such as the universities and the research associations. It also plans and coordinates the government's association with industry in the promotion of research, and its help in shaping the government's attitudes towards the promotion and maintenance of research associations is important. It also recommends the awarding of scholarships and fellowships to facilitate the training of government research workers, and can promote cooperation in scientific matters with governments and organisations in other countries as well as with international organisations.

Science Budget

A comprehensive Science Budget, prepared annually to assist the council in advising government on appropriate allocation of resources to various areas of scientific activity, enables all government science activities and science grants to be dealt with in the context of one forward programme. Each department's work is classified according to a dozen major activity headings, rather than by scientific disciplines. These groupings are agriculture, forestry, fisheries, minerals, manufacturing, building and construction, transport, the natural environment, the social sciences, human health, fundamental research, and what is termed other scientific services. These major activity groups are subdivided into thirty-seven categories, in which the council ascertains what work is under way, the resources devoted to it and the relevant cost. It also obtains forecasts of resources and costs needed to maintain existing levels of effort in each group over a forward-planning period of 3 years. It analyses new work and any extension of existing work that is proposed, and the benefits predicted to accrue from it. From this background information, the council recommends to the government what it considers desirable growth rates in scientific manpower for each activity, with an estimate of the likely cost. Priorities in allocation of manpower are a prime consideration in recommendations, because manpower is the most common and constant factor in scientific planning and expenditure.

The government then decides on an appropriate growth rate—it is 5 per cent overall for 1973–74 and is expected to remain the same next year—and within this approved frame-

work the details of each department's research efforts are agreed on.

Science Budget allocations for the 1973-74 financial year (excluding supplementary estimates still to be announced at time of writing) are shown in Tables 1 and 2.

Table 1 Science Budget Allocation 1973-74 by Activities

Activity	Direct departmental allocation* \$ thousand	Grant allocation* \$ thousand	Total allocation* \$ thousand
Agriculture	14,934	2,097	17,021
Forestry	3,380	39	3,419
Fisheries	1,379	28	1,407
Minerals	1,066	124	1,190
Manufacturing	2,087	172	2,259
Building and construction	856	214	1,070
Transport	722	51	773
Natural environment	8,634	244	8,878
Social sciences	435	256	691
Human health	625	14	639
Fundamental research	5	707	712
Other scientific services	812	44	856
Public buildings	2,200	—	2,200
Total	37,125	3,990	41,115

*\$NZ1=£0.62=\$US1.49

The council's role is at all times advisory; formulation and implementation of research programmes are the prerogative of departments; government funds for science are voted by parliament to the departments and not to the council. The council ensures that overall priorities are observed and that government receives a good return for its substantial investment in science. The council observes the way the science programme is being implemented by visits to research divisions and stations, primarily by its three advisory committees. It relates its overall recommendations to national plans and targets through its function as a sector council of the National Development Council.

University Research

Medical research is the province of the Medical Research Council, but the NRAC is concerned with the place of the universities in New Zealand research. The six universities receive most of their finance from the government as block grants at five-yearly intervals. Part of these grants, \$700,000 in 1973, is allocated by the University Grants Committee (UGC)

to research. This allocation shows as part of the Science Budget in expenditure by the Department of Education, but there is also considerable provision for research by staff and students in the balance of the block grant paid by the UGC to the universities to meet running costs. The Science Budget provision also includes annual grants to certain universities to support research institutions established with the cooperation of the government, such as the Agricultural Engineering Institute and the Tussock Grasslands and Mountain Lands Institute at Lincoln College, and the Poultry Research Centre at Massey University. Increasing use is being made of the universities through the letting of government research contracts, principally through the Department of Scientific and Industrial Research, which will spend an estimated \$61,000 on contracts in 1973-74.

Industrial Research and Development

The other major source of government funding of research is the Industrial Research and Development Grants Scheme, established in 1969 and administered by the Department of Trade and Industry. This provides for grants and subsidies to corporations and persons who have undertaken industrial research and development in New Zealand for the benefit of New Zealand. Government grants for industrial research and development projects under this scheme in the year ended March 31, 1973 totalled \$1.16 million.

Highlights of Past Year

Improved auditing capacity by the council of research work in government institutions has resulted from the establishment of the three advisory committees to focus the attention of experts in various fields on a continuous review of research priorities.

A comprehensive review of the most appropriate type of government funding of the ten research associations, based on an evaluation of their effectiveness and appropriate rates of growth, is well advanced. There may be a need for a different sort of funding from the traditional dollar-for-dollar subsidies. Some restructuring of associations could also be timely to encourage them to work more closely together where there is a need for a multidisciplinary approach to research problems.

Another form of assistance to industry being investigated is industrial and production technology. Research which could bring widespread benefit could include the use of mini-computers for process and production control. The council is investigating the needs of the textile industry as a pilot project with a view to establishing a methodology which might be applicable in other sectors of industry.

The country's present productive capacity is in no small measure due to its excellent agricultural research institutions. The council has been reviewing the work of several government research stations to assess the balance of research effort between them. Two areas of concern have called for closer examination. The council is investigating the approach to solving the pasture pest problems which are so adversely affecting many of New Zealand's farming areas, and has recently reported on proposals to reorganize and expand fisheries research within the Ministry of Agriculture and Fisheries. One of its committees is also giving priority to the need to coordinate freshwater research, in which many agencies are working on similar problems.

The council is also reviewing the need for overall organization in social science research, and has discussed with the University Grants Committee ways of encouraging research relevant to the national interest. The council considers there is need to strike a balance between the universities continuing to encourage fundamental research and the concern of the government to ensure that sufficient attention is given to post-graduate training in fields of national importance. The legiti-

Table 2 Science Budget Allocation 1973-74 by Departments

Department	Direct departmental allocation* \$ thousand	Grant allocation* \$ thousand	Total allocation* \$ thousand
Agriculture and Fisheries	9,844	613	10,457
Defence	841	5	846
Education	61	915	976
Electricity	5	8	13
Forest Service	2,832	36	2,868
Internal Affairs	306	—	306
Justice	42	2	44
Labour	177	4	181
Lands and Survey	—	12	12
Maori and Island Affairs	—	10	10
Scientific and Industrial Research	15,235	2,195	17,430
Social Welfare	109	10	119
State Services Commission	61	—	61
Transport	3,687	23	3,710
Works	1,725	157	1,882
Public Buildings	2,200	—	2,200
Total	37,125	3,990	41,115

*\$NZ1=£0.62=\$US1.49

mate requirements of academic freedom and the national interest can probably only be met satisfactorily if substantial government funds are provided through more than one channel. One such channel should naturally continue to be direct to the university system and the other through government departments by way of long-term grants, fellowships and short-term research contracts. Such a system would reconcile the autonomy of the universities with the legitimate interests of government in the national welfare. It would also serve to improve understanding and communication between university and government scientists to their reciprocal advantage.

Council's Future

New Zealand's research resources are limited. We must ensure that all are used to the full, and that the research is relevant to our needs. It is essential in a small country like ours to concentrate on those areas we know best and where we have a special contribution to make, drawing on the resources

of larger countries for basic research in areas outside our competence and limited resources. The danger at present is a tendency to spread our research efforts too broadly and to investigate related aspects of the same problems without sufficient planning. A closer relationship between the research efforts of the government, the universities, technical institutions and industry is vital to make our research more truly national and product-orientated. We shall also probably need to expand the system of intergovernmental agreements of the type announced in September between the United States and New Zealand, to facilitate cooperation and the exchange of information and scientific expertise. In determining future government research priorities, we shall need to pay more regard to research done by other organizations. I believe the NRAC will move away from concentrating on details of government departmental research into the broader field of determining an overall policy that will be needed if New Zealand is to meet its economic and social objectives more effectively and realistically.

Scientific Research in New Zealand

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In this article an attempt is made, with particular emphasis on university experience, to give an overall view of scientific research in New Zealand and its special features as seen through the eyes of a research worker.

IN this article I describe scientific research in New Zealand and compare it, where possible, with the practices in the United States and Britain. In order to give an overall picture of scientific research in New Zealand I will first describe the funding and organisation of research within the university system and within the Department of Scientific and Industrial Research (DSIR). An attempt will then be made to sketch the broader features of scientific research within the universities.

New Zealand Universities

There are seven autonomous university institutions¹ in New Zealand, all funded by the central government through the University Grants Committee (UGC) on a quinquennial basis. They had a total of 35,000 students enrolled in 1972. In contrast to the situation which exists in the United States, academic staff in New Zealand universities are paid on the basis of a twelve-month year. This means that full academic salaries are met from the quinquennial grant. In addition technicians' salaries and day-to-day running expenses are also met from this source. The maintenance and running expenses of buildings housing both teaching and research are also a charge on the quinquennial grant. Their actual construction costs are funded separately, but still, through the UGC. Research equipment

can sometimes be bought from 'setting up' grants made available when a new building is occupied, providing its use in teaching can be justified. Other research costs are funded from several sources, the chief ones being:

- (i) Research Grants Committee of the UGC. The awards² made by this committee in 1971 were NZ\$612,000* and its budget for 1973 is NZ\$700,000. Most of this money is used to purchase research equipment.
- (ii) Research committees of the individual universities. The budget of the Research Committee of the University of Auckland for 1973 is NZ\$50,000. (This university, the largest in New Zealand, has 9,500 students of whom 1,050 are enrolled for doctoral or masters degrees.) At present this committee seeks to satisfy the research needs of individuals who need rather small grants for minor pieces of equipment, microfilm, books, travel and field expenses and the like.
- (iii) Medical Research Council³. In 1972 expenditure by this body was NZ\$1.87 million.
- (iv) The Medical and Scientific Research Committees of the National Lottery Board⁴ each disbursed NZ\$125,000 in 1971.

The concept of funding a major facility (for example, an accelerator or reactor) and assuming its running costs for the first few years is unknown in New Zealand. Instead, research grants are made to individuals for a specific research project. This contrasts vividly with the way in which nuclear physics research, for instance, is funded in universities in the United States by the National Science Foundation (NSF), where grants are generally made to a 'principal investigator' who is the director of a major facility (for example a tandem accelerator). Any suggestion that such a system should operate

*The present exchange rates are £1.00 = NZ\$1.61; NZ\$1.00 = US\$1.49

in New Zealand would probably be severely criticised especially by the sub-professorial staff in the universities. The advantage of funding the individual directly is that it is relatively easy for a research project in a new field to be started, especially one which does not demand a large investment at the beginning. The major drawback is that research activities in many departments become very fragmented: the independence of the academic is no myth and with few constraints each staff member tends to go his own way.

Because of the small size of the scientific community in New Zealand, the allocation of research money is undertaken by the various research committees. This is very different from the method adopted by the NSF, where all grant proposals are refereed by at least one peer scientist. When it comes to judging the real worth of most research proposals, the committee members would probably feel that they were acting as informed laymen rather than as experts in the subject. That the system works as well as it does is a considerable tribute to the abilities of the people who make up the various research committees. It has, however, been pointed out that it is often difficult for such a committee to separate the significant from the trivial research.

DSIR Support for Research

The DSIR is an example of a government department engaged in research. Its expenditure in 1971 (ref. 5) was NZ\$12.1 million, whereas in 1970 it was NZ\$10.4 million. (The comparable figure⁶ for university research, including all MRC funded research was NZ\$4.3 million in 1970.) The DSIR accounts for approximately 44% of government expenditure on science. Research in agriculture and the environment accounted for NZ\$7.5 million of its 1971 expenditure. Very properly, there is a heavy commitment to applied research and development, and the individual scientist will generally have less freedom than his counterpart in the universities to choose his own research projects. Requests for funding are channelled through the normal administrative pyramid where relative priorities are established at several different levels. (This, however, is as it would appear to a man wishing to initiate some particular research project. Probably a more general procedure is that the director of a research institute will call for proposed expenditures for the next year from his section leaders and the proposals assembled by him will move up from there.)

(In the universities by contrast, priorities are established only at the very top—by the UGC Research Grants Committee.) Normally before a major piece of equipment (more than NZ\$5,000) can be bought, it must be in the year's budget. Even then it is still subject to Treasury approval. A further complication is that money not spent in one financial year cannot be carried over into the next. To overcome this problem, however, an 'advance order' may be made against next year's expected capital equipment budget if, for instance, delivery time is expected to be long. In an emergency, of course, money budgeted for 'consumables' may be used to finance what would normally be a 'capital equipment' item, a procedure which is not uncommon in most countries.

Research in the Universities

What conditions are necessary to encourage the successful prosecution of scientific research in New Zealand? As in all countries the first prerequisite is adequate funding. In addition, because of New Zealand's remoteness and small size, additional criteria need to be satisfied. Turning to the first point, the latest available comparative figures⁷ are for 1967. In that year expenditure *per capita* by New Zealand on domestic research and development was approximately one-third of the expenditure by the USA and two-fifths of that by Britain and Canada.

(In a study by the Organisation for Economic Cooperation and Development on reviews of national science policy, the following comparisons are made for 1967 of gross domestic research and development expenditure for economic and social purposes (in US \$ per head of population): United States \$34.5; Britain \$24.0; Canada \$23.7. For New Zealand the comparable figure⁷ was \$10.00) My impression is, however, that since 1967, the relative position of New Zealand has improved somewhat. It is obvious too that the demand for research support within the university system far exceeds the supply; in 1971 the research committee of the UGC received 287 applications for grants totalling NZ\$2.9 million. They were only able to make awards totalling NZ\$0.6 million to 122 applicants². The positions of some departments are perhaps not quite as bad as these figures would indicate. Setting up grants received by a department upon occupying a new building have often been a great help in obtaining necessary research equipment, providing its use in the teaching programme (including graduate teaching) is justifiable. Almost every avenue of scientific endeavour now needs adequate computer facilities. Until very recently these were woefully inadequate in almost all New Zealand universities. With the installation, at a cost of approximately NZ\$3 million, of five Burroughs 6700 computers within the universities, the situation has now improved a good deal. Remote terminals, however, are all but unknown and the computers are still short of memory and peripheral equipment; computer facilities in New Zealand universities are still rather modest when compared with those available in comparable universities in the USA or Britain. In many cases technical staffing of science departments appears to be adequate when compared with overseas laboratories. Although academic staff have almost always spent time in overseas laboratories, technical staff rarely have. For this reason it is sometimes rather hard to develop in New Zealand the technical competence in certain specialised areas which can be taken for granted in laboratories in the USA or Britain. Many skills at the technical level are best transferred by direct contact at that level. Finally there is much variation in the standard of accommodation for both people and equipment. Those who are housed in new buildings are obviously better off than those in old or interim accommodation.

Small size

Returning now to the problems peculiar to New Zealand, perhaps the most noticeable feature is that the small size of the scientific community means that it is difficult, or impossible, to obtain the stimulation which seems so vital for worth-while research to take place. The most serious problem is generally the lack of critical listeners with an interest common to your own, whether it be research or teaching. This was stated somewhat differently by a colleague: "there is no recognition of your work within New Zealand". This deficiency, however, is exacerbated by artificial constraints which isolate the staff in the different universities from one another. (The Research Grants Committee through their policies of funding the individual contribute further to this isolation. My colleague's comment also reflects the fact that, quite sensibly, the development of the same research interests at different universities has not been encouraged.)

For instance, in three years as Professor of Nuclear Physics at Auckland I have not been asked to give a seminar or colloquium in any university in New Zealand other than my own (although I have given a short course at the Institute of Nuclear Sciences). In my time in the USA, however, I was invited to speak at Berkeley, Stanford, Yale, University of Pennsylvania and Brookhaven National Laboratory. The chief reason for this lack of interaction between the different universities would appear to be the difficulty of obtaining money to pay the travel costs of seminar speakers. Within even a major department there is no such thing as a seminar fund and each time you wish

to invite a speaker, a special application must be made. It is a hardy seminar organiser who persists for very long under such a régime. In addition, although cooperation between government laboratories and the universities is generally good, there is at least one area where such collaboration has been frowned upon in the past by the government department concerned. We certainly cannot afford the luxury of this sort of insularity in such a small country. Another artificial constraint is the virtual impossibility of obtaining support to go to overseas conferences (especially in the Northern Hemisphere). Even when money is forthcoming, the idea of full payment of expenses is quite foreign and almost without exception the individual concerned will need to dig quite deeply into his own pocket. In addition, provisions for conference travel within Australasia are inadequate; at Auckland the Department of Physics, with a permanent academic staff of 24, has been allocated NZ\$1,000 for next year for such purposes. Until this year it has been virtually impossible to obtain such support for PhD students. The situation now is not much improved.

Sabbatical leave provisions for New Zealand academics seem to be somewhat more generous than are those of their counterparts in most universities in Britain and the United States. This statement, however, is certainly not true of scientists employed in government laboratories. Although they find that provisions for travel within New Zealand are adequate, like their university counterparts, money to attend overseas conferences is extremely difficult to get. There is no doubt that a vigorous policy of secondment to, and staff exchanges with, laboratories overseas would greatly benefit scientific research in New Zealand. (The cost need not be great.) Sabbatical leave is, in general, available to all staff members at senior lecturer or higher (equivalent in the USA to Associate Professor or higher). It generally consists of one year of leave (after six years of service) on full salary plus fares for the individual.

Delays and Advantages

An important feature of any good research laboratory is its holding of scientific journals and books. With some exceptions these are reasonable. Time of arrival, however, is also important. Typically *Physical Review* is between two and three months late. There is a similar problem with conference proceedings and books ordered from the Northern Hemisphere. Some may argue that this is not important. The inability to read the journals until three months after one's colleagues in the Northern Hemisphere, however, is not conducive to a stimulating research environment. An obvious solution, if economically feasible, is to airfreight at least the important journals and conference proceedings.

Delays occur when ordering equipment. Most equipment purchases must be made through a centralised purchasing section of the Education Department in Wellington, the capital city. I am told that there are advantages in this, but its only apparent effect is to increase the time taken to obtain equipment by about two months. A solution to this problem would be for each university to have its own purchasing department. An additional characteristic which stems directly from New Zealand's small size and isolation is the difficulty of initiating new research quickly if it involves the purchase of a new type of equipment. For example, you may decide that a certain type of spectrometer would probably be the best tool to solve your problem. In the United States or Britain a telephone call to two or three manufacturers would probably result in an offer to demonstrate the instruments within a few days. You could then make a judgement of the worth of the equipment by using it yourself. At 12,000 miles this is not often possible and probably even with one's own limited knowledge you know more about it than anyone else in New Zealand: there is not even anyone to talk to. The other side of this coin is that, in a small laboratory,

it is often relatively easy to assemble quickly a number of people with the required skills to undertake a particular project. If no major new equipment is required such an undertaking can often be concluded more quickly than in a larger institution.

Some scientists, however, are at an advantage working in New Zealand. In most laboratory-based research, a worker is in direct competition with his colleagues in the generally better equipped laboratories overseas. On the other hand, there are quite a large number of research areas where the researcher in New Zealand, because of New Zealand's geographical position (even it's remoteness!) or some other special feature, can find that he is in a better position than a researcher in a more advanced country. Examples that spring to mind are oceanography (New Zealand is in the middle of the water hemisphere), geothermal energy investigations and a number of areas in agricultural research. The smaller size of research establishments in New Zealand also means that a scientist is forced to be less of a specialist and to master a wider variety of skills than in large laboratories.

Shortage of Fellows

Finally, perhaps the biggest deficiency of all is the paucity of post-doctoral fellows. In every good university or national laboratory I have ever had anything to do with in the United States or Britain, the post-doctoral fellows (and the similarly situated non-tenured assistant professors in North America) have played a very large part in the research activities. The reasons are not hard to find: they are young, they can devote a large fraction of their time to research and work harder at it than many established researchers. They are often thoroughly conversant with their subject. With an academic staff of about 500, there are six post-doctoral fellows at the University of Auckland (these figures exclude the medical school). The situation is not much different at the other universities. The contrast between the funding of equipment purchases which in some areas is seen to be adequate and the demands for post-doctoral fellows is that the latter must compete with all the other demands put on a university's block grant, whereas the funds available to the research committee of the UGC have been earmarked for that purpose. (They are² "... sequestered from the gross amounts calculated for the total block grant and are intended to be used principally for large purchases of equipment. . . .")

Many of the above points would apply equally well to scientific research in government laboratories in New Zealand. I would be surprised if they had no relevance to the Australian scene. Perhaps it should be said finally that the conditions under which scientific research is carried out in New Zealand have improved a great deal in the past few years. I think they will continue to improve in the near future. If it is felt that I have been unduly critical then my plea is that until we identify deficiencies in the system, we cannot overcome them. Furthermore, there is no point in undertaking scientific research in New Zealand unless you can do it at least as well as it can be done elsewhere.

¹ *Reports of the University Grants Committee for 1972*, App. E3 to the Journals of the House of Representatives of New Zealand (JHR) (1973).

² *Report of the Research Committee* (University Grants Committee; 1971).

³ *Report of the Medical Research Council of New Zealand*, App. E11 (JHR) (1973).

⁴ *Report of the Lottery Board of Control*, App. H22B (JHR) (1972).

⁵ *Report of Department of Scientific and Industrial Research*, App. H34 (JHR) (1972).

⁶ *New Zealand Year Book* (Department of Statistics, Wellington, 1972).

⁷ *ibid.* (1970).

Science Under an Australian Labor Government

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In the course of a special interview during the preparation of this article, Mr William Morrison, the first Australian Minister for Science, said that there are absolutely no votes in science in this country. For scientists in Australia, looking for a greater public and political involvement in their work, this realistic assessment brings small comfort. For the Labor government, twelve months in office this week (after twenty-three years in the wilderness of opposition), it is unfortunate that the largely constructive and uncontroversial record of the minister and his new Department of Science has had no effect on the fortunes of the Labor Party.

At the time of the last report in *Nature* on the politics of Australian science¹, as demonstrated at the Australian and New Zealand Association for the Advancement of Science (ANZAAS) Congress, the Whitlam government was carrying all before it. But in the three months since then there has been a rapid and marked fall in the degree of popular support for the Labor party and its policies. The previously dominating profile on the domestic scene of Mr Gough Whitlam and his government has been eroded by the loss of a crucial by-election, by the political effects of rapid inflation, by a series of mishandled announcements of major decisions, and by the rejection in the spring session of Parliament of a number of important measures by a hostile Senate where the government is in a minority. An early honeymoon for Labor in the press has now changed, even among enthusiastically radical journalists, to a critical and sceptical mood about the style and substance of Labor in power.

All this is germane to any assessment of the present state and future prospects of science in Australia. A minor Cabinet reshuffle last month left Mr Morrison still holding his two portfolios of External Territories and Science. Self-government for Papua New Guinea, the second major stage in the territory's move towards full independence, is due to be implemented on December 1. Then, Mr Morrison's major preoccupation will ease and he could be expected to have more time for the Science portfolio.

Such expectations are, however, qualified by speculation that a further Cabinet reshuffle predicted for early in 1974 could include a promotion for Mr Morrison out of a relatively low ranking ministry.

Labor has had a policy for science and technology written formally into its manifesto for some time; the latest amendments list thirty-three points of policy, mostly couched in general terms. The preamble talks of integrating science policy with social and economic policy in achieving national goals. Point 3 of the Platform on Science and Technology specifies "a minister with direct responsibility for science and technology". But on assuming office in December 1972, Mr Whitlam only established a Ministry for Science; technology was left out and was not included by name in any other ministry.

Under the preceding Liberal and Country Party coalition government, the administration of science had been tagged on to the big vote-getter and budgets of education. In the formal hierarchy of ministries which then obtained (under Labor, all twenty-seven ministers are equal in formal status and salary, even the Ministers for Sport and Foreign Affairs), the Ministry for Education and Science was a powerful political springboard. Indeed, the first Minister for both Education and Science, the then Senator John Gorton, went on to become Prime Minister, albeit for a short time. Gorton and his several



Fig. 1 Mr William Morrison (left), Minister for Science, and Dr J. R. Price, Chairman of the CSIRO.

successors were at pains to deny that a national policy for science was possible; but apart from setting up a project to collect data on the financing of research in Australia, they never tried seriously to test that proposition. Yet, the principal achievements of Australian science and its broad directions were settled under the oversight and funding, if not the declared direction, of the Liberal-Country Party régime; with few exceptions, these have been accepted as a proper inheritance by the Labor Party.

The CSIRO (Commonwealth Scientific and Industrial Research Organisation) grew under the previous government to its present eminence in size and reputation, both locally and internationally. The CSIRO budget for 1972-73 (the Australian financial year runs from July to June) was \$A68.6 million, of which \$A56.1 million came from the Treasury and the remainder from various industries, predominantly rural, for supportive research.

The Liberal-Country Party coalition instituted some order and growth into the funding of research outside CSIRO with several grant schemes; these were started in the 1960s, and without exception have been continued by the Labor government. The ARGC (Australian Research Grants Committee) disburses funds to individuals and small teams in universities, predominantly but not exclusively, in science. The NHMRC (National Health and Medical Research Council) gives money for clinical research and medically oriented biology. The IRDG (Industrial Research and Development Grants) comprise money for research and development activity within commercial industry. The full picture is difficult to unravel, though, because a number of government departments

have sizeable research budgets, each university has its own funds for allocation on departmental bases, some universities benefit from industrial support and general benefactions, and there is a fair amount of silent support for medical research from drug companies. Within the Department of Science, project SCORE (Survey and Comparison of Research Expenditure) is gathering basic data on these points.

Some idea of the level of support can be gained from the triennial budget for 1973–75 of the ARGC; this amounts to \$A20 million and four areas have been specifically earmarked—\$A0.9 million is allocated for new initiatives in upper atmosphere science; \$A0.9 million for new initiatives in marine science; \$A0.65 million for multidisciplinary research and \$A0.55 million for a major 'national facility' in NMR spectrometry. Four weeks ago the first, eagerly awaited annual list of detailed grants awarded under the Labor government were announced; the total figure of \$A6.5 million was only a very modest \$A0.7 million larger than the last grant under the previous government. The NHMRC has \$A13.5 million to disburse in the same triennium.

The mood of researchers in Australia has changed over the past decade from one of skimp-and-scrape, often of despair with a consequent wastage of talent to overseas, to moderate satisfaction with the degree of support. Research funds are spread fairly widely (there are a thousand recipients of the latest ARGC funds); Australian egalitarianism peeps through, to the detriment, however, of some world-standard projects in astronomy which demand major capital grants to get off the ground. The odd political fact was that the Liberal-Country Party politicians could never articulate their achievements in this field. The lack of specialised science correspondents in the media did not help, and this situation is hardly different now. As Mr Morrison said, there are no votes in science in Australia. Yet there was, and is, much to show off. At least Mr Morrison's publicity efforts, coupled with the establishment of a separate Department of Science, have given the organisation of science in Australia a more cohesive identity than previously.

The spectacular instruments of the Australian astronomers have been highly productive of important discoveries—radio-astronomers using the big dish at Parkes gained fame by their studies of quasars, their colleagues at the Molonglo (or 'Mills') Cross through work on pulsars, those at the Narrabri Stellar Interferometer for classical measurements of the sizes of stars, and those at the Culgoora radioheliograph for their moving pictures of the radio sun. Australia won its first two Nobel Prizes for medical research (interestingly, before significant government funding started) through the virologist and immunologist Sir Macfarlane Burnet and the physiologist Sir John Eccles (they were joined as fellow laureates this year by the novelist Patrick White). The development of analysis by atomic absorption spectroscopy in Melbourne and the remarkable Self-twist Spinning Machine of the Geelong laboratories are two multimillion dollar export earners from original CSIRO work.

Under the Labor government, the Minister for Science has gained control of some of the scientific activities which were previously dispersed under various other Ministers, but even now does not have government-sponsored research to himself, any more than did his Liberal-Country Party predecessors. The Education Department looks after universities, Health has the NHMRC scheme, Minerals and Energy has the Bureau of Mineral Resources and the Atomic Energy Commission (now sadly moribund as regards its principal purpose, nuclear power, which has been postponed indefinitely by the government), Supply covers defence research and Secondary Industry has the IRDG. These inheritances have been joined by two new departments interested in scientific and social research, Environment and Conservation, and Urban and Regional Development. Prominent among the ministerial staffs of these creations (including Science) have been members of the small but previously vocal Social Responsibility in Science

Societies, which have fallen remarkably silent under Labor rule.

Orientation towards social needs and multidisciplinary approaches are the special stamps Mr Morrison wants to place on Australian science ('people science' is the ungrammatical slogan coined by his staff). With this in mind he first looked critically at the CSIRO. Dr J. R. Price, Chairman of the 6,600-strong organisation, reflected on the changed mood in the CSIRO's twenty-fifth annual report, released to Parliament last month. He contended that it is unfortunate and incorrect to use the terms 'people oriented' and 'industry oriented' in such a way as to suggest they are irreconcilable. Research which benefits 'industry', he wrote, also benefits 'people'—and conversely. A case cited is the process for polyunsaturated meat and dairy products², patented by the CSIRO, which was licensed to a company controlled from overseas before the Labor Party came to power and imposed restrictions on licensing to foreign companies. The CSIRO has, however, reflected the political and social climate through regrouping and redirecting some of its existing divisions and creating new ones. For instance, the new Divisions of Land Resource Management and Land Use Research have been grouped with the older Division of Soils; together they will provide basic information (ecological, hydrographic, geographic and so on) for planning the development of Australia's coastal fringe, where the majority of Australia's 13 million people are being crowded, in an uncoordinated fashion, into what may become the world's longest conurbation. These and other moves, like the employment of a few social scientists, seem now to have smoothed over a somewhat sticky relationship between the CSIRO and the Minister for Science in the first frenetic months of Labor rule. In the August budget, the CSIRO won its first significant expansion in professional staff for some years.

The immediate future of Australian science will be dominated by four main growth areas. First, astronomy will be boosted by the commissioning throughout 1974 of the sophisticated 3.9 m (154 inch) Anglo-Australian optical telescope. Second, marine science is being encouraged by the imminent establishment of the Australian Institute of Marine Science as well as several other projects. Third, medical research will be broadly based, but will continue to develop centres of excellence in physiology and immunology. Fourth, solar energy research, a field in which the CSIRO devices for low grade heating probably lead the world, will be supported politically and popularly; the CSIRO is establishing a special small unit to study the whole, broad question.

Among the unique initiatives of the Labor Minister of Science has been a popular move into the definition and enforcement of consumer standards on sound scientific grounds; a special commission, headed by a physicist, has been set up for the purpose. A Biological Resources Council has recently been established to make an inventory and collection of the country's flora and fauna, which, considering their uniqueness and diversity, are remarkably unknown. And the Organisation for Economic Cooperation and Development (OECD) has been invited to investigate Australian science.

To assist in the development of a policy for science and technology, the previous government established, rather late in the piece, an Advisory Committee on Science and Technology; this was quickly axed by Mr Morrison soon after taking office, with the stated intention of implementing the fourth plank of the Labor Party platform, namely the establishment of a Science Council. This has, however, proved more difficult than was thought at the time of winding up the previous ACST. Until the minister can push through Cabinet and Parliament the necessary legislation to set up this Science Council and give it independent powers, a national policy for science in Australia is likely to remain largely *ad hoc* and in a political backwater.

¹ *Nature*, 244, 534 (1973).

² *Nature*, 245, 10 (1973).

Seismological and Geothermal Research in New Zealand

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In both solid Earth and atmospheric sciences New Zealand has international responsibilities stretching from the equator to the south pole and from 165° E to 155° W, representing almost 6% of the Earth's surface.

WITHIN the New Zealand region are many interesting geological and geophysical manifestations. New Zealand itself consists of a currently active plate margin superimposed on an upper Palaeozoic-lower Mesozoic geosyncline, though this over-simplified view ignores many aspects of New Zealand's geology. It does, however, define fairly well the areas with which the work of most of the country's Earth scientists has been concerned. The Pacific-Indian plate margin is readily identified as continuing to the Kermadecs and Tonga to the north and, in the other direction, to the triple junction south of Macquarie Island. The New Zealand Geosyncline is disposed in a complex series of sinuous curves from New Caledonia perhaps to the Chatham Islands. From the large variety of work being done in this region by Earth scientists we shall discuss two topics. In one, seismicity, New Zealanders have often held views at variance with workers in other regions. In the other field, that of geothermal energy, development has been led by New Zealand for the past two decades.

Seismicity

The most obvious effect of the plate margin on the community at large is the risk to life and property from earthquakes and volcanism. A magnitude 7 earthquake shook Wellington in 1848, only eight years after the founding of the settlement, and was followed in 1855 by an even closer earthquake, now presumed to be of magnitude 8. It was from a study of this earthquake that Sir Charles Lyell made one of the earliest associations of contemporaneous fault breakage accompanying a major earthquake. The first Milne seismographs were installed at Wellington in 1900 and at Christchurch a year later. From these have grown the present network consisting of twenty-six stations in the main islands and eight in outlying territories extending from Samoa to the Antarctic. New Zealand's geophysical involvement in the Pacific stems from the First World War, when the established Observatory at Apia in Western Samoa passed from German to New Zealand administration. There are now five New Zealand-controlled seismograph stations in the Pacific to the north of New Zealand, covering one of the most active seismic areas of the Earth. To the south, stations at Campbell Island and Scott Base are in completely different geophysical environments. The two main strengths of the New Zealand seismograph network are its extent and its unified control. All records from the network are finally analysed at the Seismological Observatory in Wellington. This enables the earthquakes of the whole region to be examined together, and the interrelationship of seismicity and other geophysical features to be evaluated.

Northern Seismic Region

A unique characteristic of northern New Zealand is that its principal geophysical phenomena (gravity anomalies and man-

tle earthquakes) pass through the continental region and thus the seismological network virtually straddles an island arc.

The most striking feature of the seismicity is the lack of correlation of shallow earthquakes with the visible geology. Whereas the deep and intermediate earthquakes form a well defined zone dipping to the west beneath the North Island and the north of the South Island, the shallow earthquakes display a 'pepper-pot' effect of wide scatter (Fig. 1). That this effect is not a result of imprecise location has been recently demonstrated by detailed micro-earthquake surveys along the Alpine and other major fault systems, carried out by New Zealand and American parties. These surveys confirm the locations given by the standard analysis of the New Zealand Seismological Observatory. The reason for this paradox seems to lie in the depth of the earthquakes. Those earthquakes that are located in the top few kilometres can often be associated with a fault trace, but much of the activity appears to be in the lower crust, and related more to underlying mantle activity than to superficial geology. Indeed there seems to be a change in earthquake mechanism from dominantly compressional for earthquakes less than 20 km deep to dominantly tensional for deeper earthquakes.

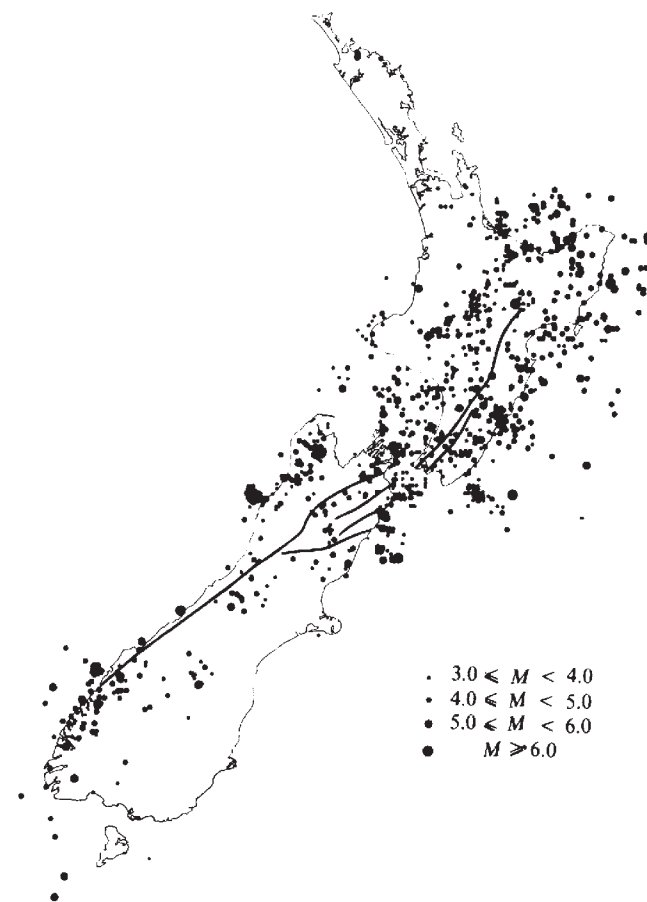


Fig. 1 Upper crustal earthquakes, 1955–66. Improvement in the seismograph network since 1966 has shown that the south-western part of New Zealand (Fiordland) is, seismically, the most active part. Only the principal faults are shown. Numerous smaller fault zones exist, particularly in the eastern half of the North Island. —, Major active faults

Alpine Fault

Like New Zealand, California also consists of a current plate margin superimposed on an older geosyncline. The many similar features of the San Andreas and Alpine Faults have often invited comparison which has, at times, become identity. But historical statistics and short-term micro-earthquake studies have both failed to identify the Alpine Fault as similar to the San Andreas Fault in the seismological sense. Earthquakes and micro-earthquakes in the central part of the South Island are not aligned along the Alpine Fault though they seem to be confined to the upper part of the crust. Composite focal mechanisms from the diffuse activity in the region obtained by a Lamont-Cornell group¹ show that a regional NW-SE compression dominates the tectonics, this direction being nearly normal to the Alpine Fault. The resulting conclusions that the Alpine Fault is now undergoing a large component of thrust faulting with consequent uplift of the Alps and that the greater part of the transcurrency pre-dated the current orogeny are consistent with much geological opinion in New Zealand. They are in disagreement with the views of some plate tectonicists who wish to have the whole 500 km shift take place after mid-Miocene.

Fiordland

The visible Alpine Fault ends at Milford Sound, one of New Zealand's most scenic localities (and its wettest). At this northernmost of the fiords intermediate depth earthquakes recommence (Fig. 2) but continue southwards for only 150 km. Shallow earthquakes persist into the Macquarie Ridge and hence to the triple junction south of Macquarie Island. Where the deeper earthquakes begin to peter out a gravity anomaly pair begins, the positive anomaly over Fiordland revealing a mantle at little more than 5 km depth and the gravity low offshore indicating probably 30 km of low density material below a sea which is 4,000 m deep. As the gravity anomalies diminish to the south the geophysical picture (Fig. 2) is dominated by the magnetic anomaly of the north Macquarie Ridge. The interpretation of the transition of the Alpine Fault to the Macquarie Ridge in terms of the complex and abrupt geophysical changes has so far defied anybody's tectonic intuition. The geological maps of Fiordland show virtually no active faulting in this, the most seismic region in New Zealand, though whether this is due to the difficulties of exploration in this rugged country is a moot point.

There is a real danger in considering that, in New Zealand, the zones of greatest earthquakes are necessarily concentrated along surface expressions of faults, or in accepting that studies of physical processes accompanying or preceding Californian earthquakes will be relevant to the understanding of destructive seismicity in New Zealand. It is true that there are many spectacular faults in New Zealand and that some of these have moved during large earthquakes, but detailed plots of epicentres show little relation to the lineations of active faults. It is from an awareness of their own environment that New Zealand seismologists have not always accepted without question the faulting mechanism of earthquake generation. From the same awareness, the general optimism overseas about the prediction of earthquakes is not unequivocally shared. However a telemetered seismic network, an order in scale down from the main network, will be established in the Wellington region during the next two years to test current theories in New Zealand conditions.

Geothermal Energy

Though generally a hazard, the plate margin makes a positive contribution to human welfare by providing heat. The thermal waters of New Zealand have been used for many years in spas, bathing pools and for house heating, but it is only twenty-five

years since the Government made the decision to attempt to use geothermal energy as a source of electric power. One field was developed quickly and the New Zealand Electricity Department's station at Wairakei, which now has an output of 150 MW, began producing power in November 1958. About the same time the large mill of the Tasman Pulp and Paper Company was sited so that steam from the Kawerau field could be utilized in the integrated energy complex of that concern. Since then development of geothermal fields has been negligible, perhaps as a result of the discovery of a large gas field (Maui) off the west coast of the North Island.

The early development of Wairakei was mainly due to engineering initiative spurred on by the United Kingdom Atomic Energy Authority's temporary interest in the production of heavy water; for the scientists were still feeling their way in matters of geothermal exploration. Since those early years,

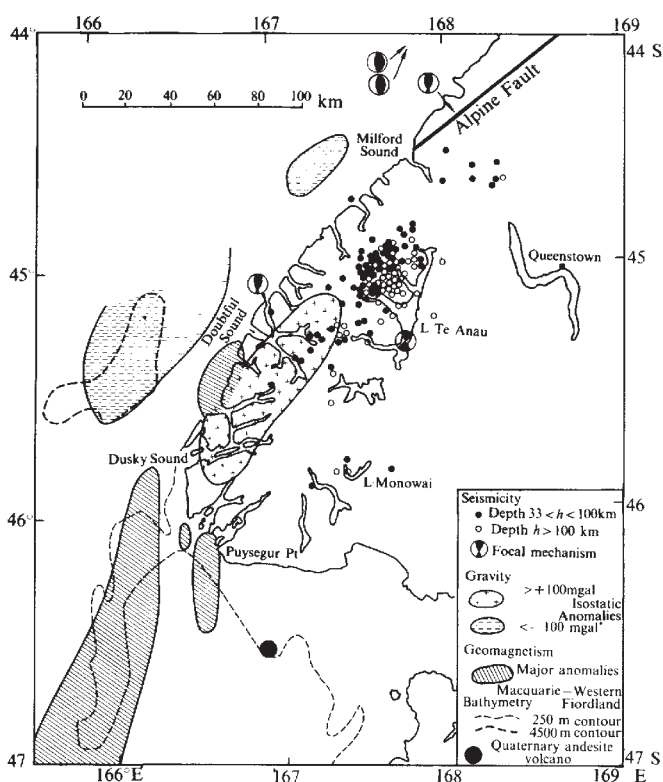


Fig. 2 Composite geophysical map of Fiordland. Subcrustal earthquakes only are shown, for the years 1966-68, 1971 and 1972. Focal mechanisms of some shallow earthquakes reproduced from Scholz *et al.*¹.

however, an enormous amount of systematic geological, geochemical and geophysical work has laid the basis for a proper appraisal of total resources and of each individual field.

Although most fields are indicated by some form of surface thermal activity, the size of the reservoir is best explored by electrical resistivity methods, for the thermal waters contain about 1,000 to 2,000 p.p.m. Cl. Figure 3 shows the fields so far delineated by electrical techniques, and it is conservatively estimated that at least 1,000 MW of power is available from these areas, the ultimate amount probably depending on permeability conditions within the fields. Although the whole gamut of electrical techniques has been tested during the past decade, including dipole-dipole and transient E-M, the simple traverse with a Schlumberger spread is still the most convenient and effective method of defining the fields.

A major problem in exploration remains—the very difficult (impossible?) one of predicting permeability or fissure availability at depth from surface measurements. Although the size

of a heat source can be defined quite well by geophysical methods, the crucial problem of prediction of draw-off rates is dependent almost entirely on geological inference, until tested by expensive drilling. Since some areas are covered by fairly recent ash showers or lacustrine deposits, even knowledge of geology can only be derived by stratigraphic drilling, and

extrapolation and interpolation of the chaotic volcanic and sedimentary rock units are fraught with difficulty; recently an attempt has been made to detect concentrations of fissures by resistivity anisotropy. Conservative estimates of power available can be made considering the system as a static reservoir. True reserves are, however, dependent on the recharge of the system; detailed, regularly repeated gravity surveys combined with levelling are being used at Wairakei to supplement well data in an effort to understand the dynamic characteristics of the reservoir.

As usual, the devotion of a large scale scientific effort to an economic objective has induced a number of intensive offshoot studies. The nature of hydrothermal alteration in rocks was the first of these, followed by the experimental geochemistry of the interactions between rock and hot-water. Perhaps the latest is the examination of currently forming base-metal and gold-silver mineralization in the Broadlands field and its relationship to mineral deposits in similar, older and now inactive environments elsewhere. The Taupo Volcanic Zone has a rapidly increasing population based mainly on timber "farming". The burgeoning problems of siting all the accoutrements of civilisation (like houses, schools, roads and cables) in thermal regions have resulted in traditional, *ad hoc* individual temperature surveys being replaced by an airborne emissive infrared survey of the major towns and their environs.

On a larger scale, the major fields seem to occur as fairly regular, vertical, hot water pipes along or just behind the volcanic front. The nature of the heat source and the mechanism of heat transfer (to the almost wholly meteoric waters) continue to preoccupy the mathematical physicists, and the geophysicists are seeking deeper sounding methods of high enough resolution to contribute to the source problem. Meanwhile the acquisition of skills in the exploration for and exploitation of this once esoteric form of energy has resulted in a great demand from other countries for New Zealand consultants—a demand which, if not carefully watched, may stultify or inhibit geothermal research and development within New Zealand.

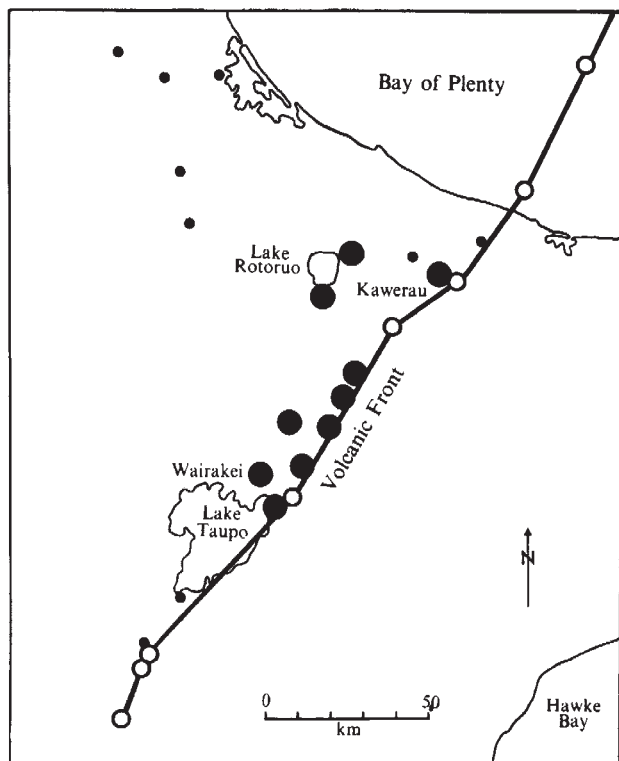


Fig. 3 Locations of geothermal fields. The volcanic front has been drawn by joining the easternmost volcanoes (○). ●, Fields where substantial areas of ground resistivity $<20 \Omega$ are known to occur (normal ground resistivity is 200 to 500 Ω). •, Other, relatively unsurveyed, areas with hot springs.

¹Scholz, C. H., Rynn, J. M. W., Weed, R. W. and Frohlich, C., *Geol. Soc. Am. Bull.*, **84**, 3297 (1973).

Earth Sciences and the Australian Continent

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Dr McElhinny discusses some recent activities and an important new development.

SPECTACULAR developments have taken place in the Earth sciences in recent years, and ideas about the structure and evolution of the Earth have changed profoundly. Because of the importance to Australia of its mineral resources, not least among the consequences of these developments has been their effect on the interpretation and knowledge of the geology of the continent and its margins. The simplified map of the surface geology in Fig. 1 shows that the western portion of the continent is dominantly Precambrian in age. This

Precambrian shield is bordered to the south by the Late Precambrian to Cambrian Adelaide geosyncline and to the east by the Palaeozoic Tasman Orogenic Zone. With the advent of plate tectonics it was at once realised that the presence of a number of serpentine belts in the Tasman Orogenic Zone could be diagnostic of the past locations of island arc complexes and consuming plate margins (Fig. 1). Ultrabasic and basic rocks in intimate association with serpentinites are suggestive of the former presence of ophiolites representing oceanic crust and mantle material, and in plate tectonic theory ophiolite emplacement occurs at consuming plate margins. It is not surprising therefore that there has been a resurgence of interest in regional geology and much rethinking of many aspects of Australian geology in terms of plate tectonic theory.

On May 31 and June 1 of this year the Queensland Division of the Geological Society of Australia held an important

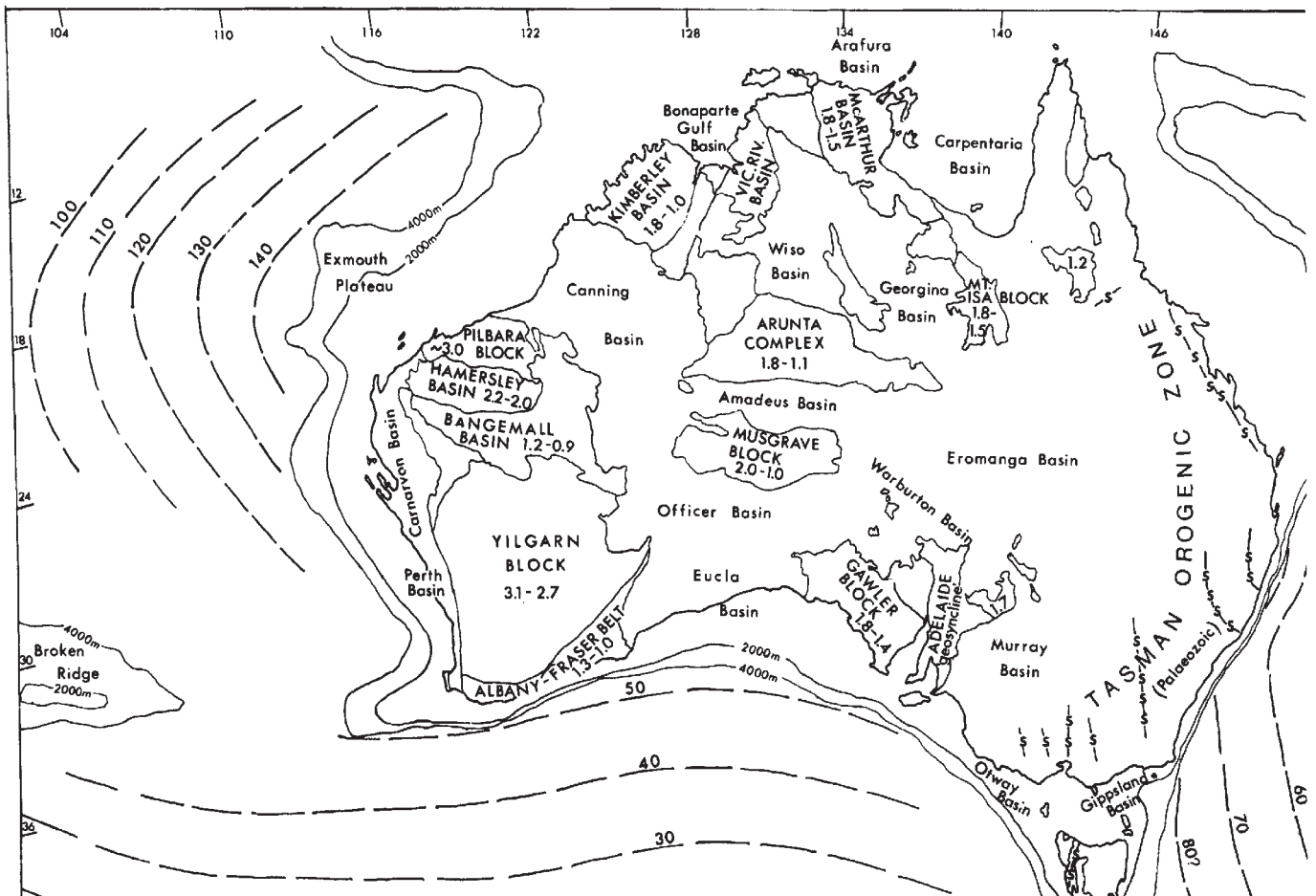


Fig. 1 Simplified surface geological map of Australia and the surrounding ocean floor. Precambrian regions are outlined with names in capitals and ages in units of 10^6 yr. Serpentine belts (S) are indicated in the Tasman Orogenic Zone. Isochrons showing the ages of the surrounding ocean floor are given in units of 10^6 yr.

symposium in Brisbane on the subject of the Tasman Orogenic Zone in honour of Professor Dorothy Hill, who retired as professor of geology in the University of Queensland. The serpentine belts in the Tasman Orogenic Zone tend to become progressively younger eastwards and it has been supposed that a series of island arc and intra-arc basins merged with the main Australian assemblage during the Palaeozoic¹⁻³. Although some of these early attempts at applying plate tectonic models to the evolution of the zone met with some criticism, they have nevertheless led to a renewal of interest in the synthesis of the wide spectrum of geological data (stratigraphic, petrological, geochemical, structural and geophysical) available for this zone. New field programmes have then been designed to test the hypothesis in great detail. There seems little doubt that the concepts of plate tectonic theory offer the most credible basis for understanding of the evolution of the zone.

Geochronological studies largely undertaken at the Australian National University in conjunction with the Bureau of Mineral Resources have established the basic age patterns of the major Precambrian cratons^{4,5} (Fig. 1). The spectacular mineral discoveries of the sixties in Western Australia have led to much detailed work being carried out in the Precambrian shield. On May 23-26, 1970 the Western Australian Division of the Geological Society of Australia held a symposium on Archaean rocks in Perth and this was attended by over five hundred scientists from Australia and overseas. The proceedings have been published as Special Publication No. 3 of the Geological Society of Australia (December 1971). There is a general feeling that the nature of geological activity has changed during geological time. The major structures have altered, though as at the present time they always appear to

have formed parts of a global tectonic arrangement. Thus of special interest is the problem of whether or not the concepts of plate tectonics can be extended back to the earliest Precambrian⁶. Palaeomagnetic data from the various cratons in Africa already show that relative movement between them must have been very small over the past 2,200 m.y.⁷, in spite of the existence of younger intervening orogenic belts of several ages. The first results from an extensive palaeomagnetic programme through the Australian Precambrian tentatively show this to be true also for Australia. It is, however, interesting to note that studies of some Western Australian Archaean greenstone belts have led to the suggestion that the development of the first primitive continental crust, now represented by these greenstone belts, was produced directly from a basaltic crust by the same process as continental crust is produced from oceanic crust in present day island arcs—by means of seafloor spreading and plate tectonics⁸. Do these belts therefore represent relics of the oldest island arcs? A more provocative suggestion has been made as a result of the extensive studies of lunar material undertaken at the Australian National University. (The group of four Principal Investigators—A. E. Ringwood, W. Compston and S. R. Taylor at the Australian National University and J. F. Lovering at the University of Melbourne—together received more of the Apollo Moon samples than any other group outside the United States.) Perhaps the Archaean greenstone belts are the terrestrial equivalents of lunar maria⁹. It has been suggested that the production of lunar maria basins was accompanied by similar impacts on the Earth. The Archaean greenstone belts are interpreted as very large impact scars, initially filled with impact triggered melts of ultramafic to mafic

composition and thereafter evolving with further magmatism, deformation and metamorphism to the present Archaean greenstone belts. Whether or not this hypothesis stands the test of time, it represents an object lesson for the critics of basic scientific research. Who would have thought that the studies by Australian scientists of lunar samples collected by United States astronauts could possibly have had any bearing on the origin of some of Australia's mineral-bearing terrains?

Precambrian stratigraphy in Australia has in the past relied on geochronological studies, which in turn have depended upon the availability of igneous rocks for dating. Some of the early work on the Rb-Sr dating of shales was undertaken in the Australian Precambrian, but the problem remains as to how one interprets isochrons drawn through the data points in terms of an age of deposition. After an initial burst of activity in this field, little has been done during the past 5 years and the uncertainties remain to be resolved. In the Soviet Union over the past decade stromatolites have become a standard tool for the subdivision and correlation of Late Precambrian sedimentary rocks and new methods and classifications have been developed. While this work was still in its infancy Professor M. F. Glaessner at the University of Adelaide brought it to the attention of the Western world^{10,11} and initiated research in this field in Australia. This work has now demonstrated the world-wide applicability of the Russian stromatolite assemblage zones¹². It is particularly appropriate that the Australian stromatolite distribution has been used to test the generality of the Soviet scheme because important pioneering work on the origin and stratigraphic distribution of stromatolites was carried out in Australia early this century. The first major treatise on stromatolites and the biostratigraphy of the Australian Precambrian and Cambrian¹³ marks a milestone in palaeontology because as yet no other detailed biostratigraphic studies in this field have been published outside the Soviet Union.

Offshore Exploration

The first offshore exploration of Australia was carried out in 1954 when the Bureau of Mineral Resources recorded an aeromagnetic survey of the Gippsland Basin. By 1964 most of the likely areas were taken up in petroleum concessions. It is only subsequent to first oil explorations that the age of the ocean floor around Australia has been determined. Between Australia and Antarctica¹⁴ and in the Tasman Sea¹⁵ ages have been found from analyses of marine magnetic anomalies in terms of the seafloor spreading hypothesis (Fig. 1). This resulted from work at the Lamont-Doherty Geological Observatory in conjunction with the Marine Geophysics Research Laboratory at the University of New South Wales. Off Western Australia the age of the ocean floor has been determined by the basement sediment isochrons plotted from results of leg 27 of the Deep Sea Drilling Project¹⁶ (Fig. 1). Legs 21, 22 and 26 to 30 inclusive of the Deep Sea Drilling Project (JOIDES) have involved exploration of the oceans around Australia and three Australian scientists have acted as Co-Chief Investigators on the Glomar Challenger (C. C. Von der Broch, leg 22; J. J. Veevers, leg 27; G. H. Packham, leg 30). Six other scientists from the Bureau of Mineral Resources and various universities have also participated in these cruises. The Bureau of Mineral Resources has just completed a geophysical survey (contracted) of the continental margins, but there is an urgent need for further work in physical oceanography and marine geology and geophysics. Australian scientists, especially those in universities, have had to rely on ships of other countries (notably the United States) or else on limited assistance from Australian naval ships. Australia has more than 12,000 miles of coastline and fronts on three oceans, but there is as yet no permanent fully equipped oceanographic ship. The need is urgent and fundamental, for without one or more ships there is little prospect of further development of oceanography in Australia.

Extensive investigations of the offshore regions have been carried out during the past decade by oil exploration companies. Government subsidies for these investigations, although soon to be discontinued, were extremely liberal but in return the exploration companies were required to submit well completion and other exploration subsidy reports to the Bureau of Mineral Resources. Such an enlightened policy has resulted in a much freer flow of information from the oil companies than in other parts of the world. The community of Earth scientists in Australia has benefited greatly from this arrangement. As a result the *Australian Petroleum Exploration Association (APEA) Journal* has blossomed into an important source publication particularly for summaries of work carried out in the offshore regions. It is at once apparent from syntheses of this work that oil geologists have very soon come to the realisation that the evolution of continental margins can be related to the new global tectonics¹⁷. Especially important is the discovery that the initial rifting between Australia and Antarctica preceded by 100 m.y. the formation of the mid-ocean ridge that resulted in the final separation of Australia and Antarctica about 50 m.y. ago. Igneous rocks of similar age to the mid-Jurassic dolerites of Tasmania and Victoria Land, Antarctica have now been found at various sites in the Otway Basin and on Kangaroo Island. These date the formation of the Otway Rift Valley between Australia and Antarctica into which was deposited Upper Jurassic and later sediments now found off the south coast of Australia^{18, 19}. The relationship of Australian continental margin oil and gas discoveries to stages in the development of continental margins and the evolution of ocean basins as portrayed by an oil geologist¹⁷ is shown in Fig. 2.

Geophysical Measurements

In January 1973 the Second International Conference on Geophysics of the Earth and Oceans was held in Sydney under the auspices of the Australian Institute of Physics, the Australian Institute of Mining and Metallurgy and the Australian Society of Exploration Geophysicists. This was as successful as its predecessor, also held in Sydney (in January 1971), and showed there has been a heightening of interest and much activity in exploration geophysics in Australia over the past few years. The gross geophysical features of continental Australia are best viewed from gravity, seismic and other measurements. The new Bouguer anomaly map of Australia issued by the Bureau of Mineral Resources is the result of

CONTINENTAL MARGIN STAGE	PERTH BASIN	WESTERN N.W. SHELF	GIPPSLAND	OCEAN STAGE	OCEANIC EVENT
Prograding	Tertiary	Tertiary		Mature	Termination of spreading
	Upper	Upper	Miocene		Sea floor spreading
	Cretaceous	Cretaceous	Pleistocene		
			Pliocene		
Readjustment	Lower	Lower	Miocene	Young	Block faulting and thinning of crust
	Cretaceous	Cretaceous	Oligocene		
	Jurassic	Jurassic	Eocene		
	Triassic	Triassic	Palaeocene		
Initial Stage	Permian	Permian	Cretaceous	Initial	Uplift
	Upper Carboniferous	Permian	Jurassic		

●, Oil; ☆, Gas

Fig. 2 Relationship of Australian continental margin oil and gas discoveries to stages in the development of continental margins and the evolution of ocean basins¹⁷.

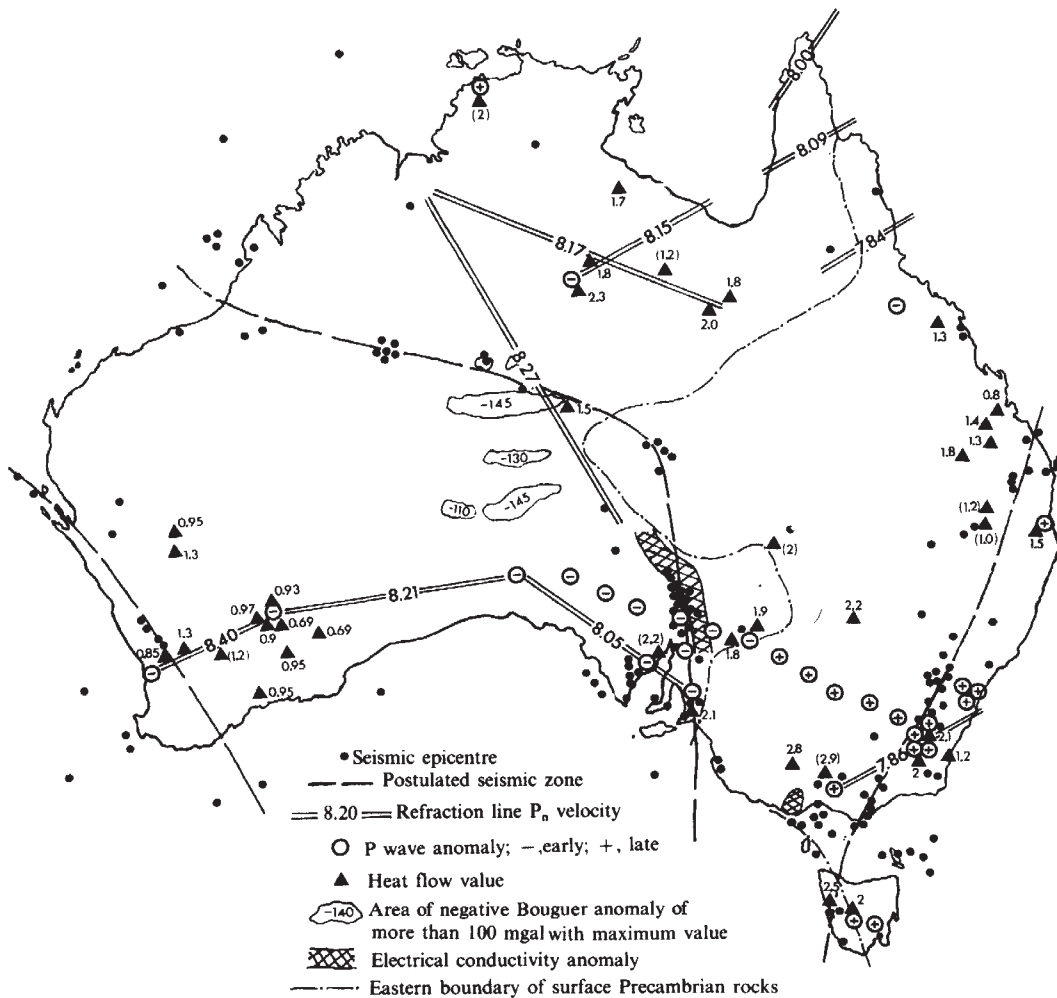


Fig. 3 Summary of certain geophysical information relating to the crust and upper mantle beneath Australia. •, Seismic epicentre $m \geq 4.5$.

measurements at over 500,000 stations; 10 mgal contours are shown derived from a minimum density of one station per 130 km², representing a better coverage than has been achieved on any other continent. Ninety per cent of the continent is now covered at this minimum density, the final 10% will be completed in 1974. The gravity map shows some interesting features including a series of alternating negative and positive anomalies in Central Australia with maximum-minimum differences of 100 to 150 mgal. Two of these negative anomalies (Fig. 3) correspond with the Amadeus and Ngalia sedimentary basins, but they are too large to be explained by the sediments alone. It seems that some feature in the deep crust or upper mantle contributes to these anomalies.

Australia is a quiet continent seismically, with only Antarctica having less contemporary activity. A few earthquakes of magnitude $m \geq 5.5$ occur each year, the largest recorded being of magnitude 7 near Meckering, Western Australia, on October 14, 1968. Earthquake epicentres^{20,21} follow three main trends (Fig. 3) and it has been suggested²¹ that these trends divide the continent into four subplates, although this is very speculative at this stage. Seismic studies of the crust and upper mantle in Australia have been reviewed by Dooley²² and Cleary²³. The discussion here will be restricted to the eight large scale refraction experiments carried out during the past seventeen years. In the first of these use was made of the nuclear test explosions at Maralinga in 1956 and in the last use was made of two large chemical explosions in 1970 and 1971 detonated during quarrying operations at the Ord River Dam site in northern Australia. The last two explosions each produced seismic amplitudes equivalent to about a magnitude 4.5 earthquake and were the first in Australia to produce reliable data beyond 1,000 km (ref. 24); P_n velocities obtained from these experiments are shown in

Fig. 3. They are higher beneath the shield and appear to increase systematically from east to west. P_1 velocities derived from these experiments are also significantly higher in the Precambrian shield region than in eastern Australia. There is good evidence for an intermediate layer in all parts of Australia, with an average depth of about 20 km to the Conrad discontinuity²³. The crustal thickness averages about 40 km, the variations in thickness being apparently unrelated to topography. Studies of P wave station anomalies²⁵ show that stations in south-east Australia have large positive residuals, whereas those to the west have negative residuals. These trends have been confirmed from observations of the Cannikin explosion in the Aleutian Islands on November 6, 1971 using a set of temporary seismic stations across 1,700 km in the southern part of Australia²⁸. The trend towards more negative anomalies appeared to be most pronounced over about 500 km near the centre of the traverse, a region that includes the eastern boundary of Precambrian rocks (Fig. 3). The results imply a strongly developed low velocity layer in the upper mantle in eastern Australia which disappears as the Precambrian shield boundary is approached.

Variations in heat flow in Australia show a similar trend to the seismic variations with very high values observed in eastern Australia and very low values in the Western Australian shield²⁷ (Fig. 3). Two studies of electrical conductivity structure of the crust and upper mantle from magnetic variation studies using arrays of twenty-five magnetometers have been made across south-central Australia in 1970 (ref. 28), and in south-east Australia in 1971 (ref. 29). The principle of mapping higher temperatures in the crust and upper mantle through the related higher electrical conductivity is of prime interest in these geomagnetic deep soundings. The first array experiment

shows a long curved conductor in the lower crust or upper mantle running north-south close to the Flinders Ranges in South Australia (Fig. 3). It might be interpreted as an upwelling in the upper mantle and because of its close correspondence with the seismically active zone, one could speculate that this represents the nascent stage in the development of a rift. The second array experiment has revealed a highly conducting zone in western Victoria, which may correlate with the Recent activity of the Newer Volcanics—possibly the remnant of a magma chamber at elevated temperatures.

New Development

Geology departments in the foundation universities in each of the state capital cities have been for many years the mainstay of undergraduate teaching and research in geology in Australia. With the rapid expansion of the number of universities during the past 20 years (there are now sixteen in Australia, including three in each of Sydney and Melbourne) the tendency in the newer universities has been to adopt the style Department or School of Earth Sciences following trends elsewhere. This reflects the recognition that the study of geology and of the Earth in general has developed so widely that it encompasses also geochemistry, geophysics and oceanography from the study of which much of the so-called revolution in the Earth sciences has evolved. Indeed many of the significant discoveries leading to this revolution were made in some of these institutions.

In 1972 the Australian National University in Canberra announced the establishment of a Research School of Earth Sciences in its Institute of Advanced Studies. This event marks a major advance in Earth science research in Australia and reflects the importance that the country attaches to such a development in the national interest. The Research School of Earth Sciences was created on July 1, 1973 with the appointment of Professor Anton L. Hales as its first director. Professor Hales was formerly Director of the Bernard Price Institute for Geophysical Research, Johannesburg and more recently Director of the Institute of Geological Sciences at the University of Texas at Dallas.

The Institute of Advanced Studies at the Australian National University was created as a national centre for research and postgraduate training in research soon after the Second World War. Under the guidance of Professor J. C. Jaeger (from 1952 until his retirement in 1972), the department of Geophysics and Geochemistry expanded progressively into new fields of Earth science research in which it achieved international prominence. By 1972 there were twenty-two academic staff and a comparable number of PhD students in the department engaged in a large variety of research programmes. These programmes form the nucleus for the new Research School of Earth Sciences which will expand to an ultimate size of about seventy academics in the next 15 to 20 years.

Research in the new school will concentrate on several main areas. The already existing activities in geophysics and geochemistry will be strengthened. These include investigations of the large scale geophysical structure, not only of Australia, but also of the entire Earth. Key fields in geophysics are seismology, palaeomagnetism and geomagnetism in its broadest sense (including geomagnetic deep sounding) geothermy and theoretical geophysics. Fundamental laboratory investigations relating to the crust and interior of the Earth include studies in rock deformation and the physical properties of rocks and minerals at high temperatures and pressures. Geochemical activities will continue to be concerned with the origins and ages of rock systems, evolution of the Earth's crust, the internal constitution of the Earth, the chemistry and mineralogy of lunar rocks and meteorites and chemical problems relating to the origin of the Solar System.

New developments will include fundamental research in economic geology directed towards the origin of metalliferous ore deposits, including especially studies of the physics and chemistry of ore-forming solutions and their precipitation. Not only have these subjects considerable intrinsic scientific significance, but also they have the greatest importance in the light of Australia's mineral resources. Consequently this development has the highest priority of the proposed new activities.

The initial developments in the solid Earth sciences outlined above will be complemented by expansion into the fluid Earth sciences. These will include geophysical fluid dynamics, involving especially examination of the circulations and interactions of the Earth's oceans and atmospheres. This is a subject particularly in need of study in the southern hemisphere generally and in the neighbourhood of Australia particularly. The discipline would also include problems of circulation in the Earth's liquid core and associated magnetohydrodynamics, as well as problems such as convective motions in the Earth's mantle. Studies in environmental geochemistry will be an interdisciplinary field embracing chemical interactions between the atmosphere, oceans and solid Earth, palaeoclimatology and the problems of photochemical air pollution and pollution in the hydrosphere and atmosphere.

Contribution

All these studies are of course related to the processes by which the Earth took on its present shape. Taken together these programmes should make a significant contribution to the understanding not just of the past history of Australia, its structure and environment, but of global geology and geodynamics in general.

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Pest Management in Australia

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The aim of pest management is to manipulate or manage pest populations by a combination of all available means so that they do not cause economic damage.

AUSTRALIA differs from other major land masses in that, almost without exception, its domestic animals and crop plants have been introduced from other countries. About half of its 600 most important insect pests and most of its weeds have also been introduced, often without the natural enemies which are so important in helping to suppress them in their native lands. It follows that the introduction and establishment of the most valuable of these natural enemies—the process known as biological control—is likely to be of special value to Australia. Indeed, the world's best known examples of successful biological control are the use of the *Cactoblastis* caterpillar against prickly pear and the myxomatosis virus against rabbits in Australia.

As in many other countries after the Second World War, the use of the new synthetic organic insecticides permitted a level of pest control never before attained. For a decade or more extensive resources were devoted to developing an improved insecticide technology and comparatively little emphasis was placed on the alternative means of control that had been the mainstay of earlier economic entomologists. As elsewhere, disadvantages of the use of insecticides gradually became evident, such as outbreaks of secondary pests and the appearance of strains of pests that were resistant to one or more of the pesticides used against them. Somewhat later, concern arose over unintentional effects on man and other non-target organisms.

Intuitively at first, and then as a deliberate policy, steadily increasing attention has been paid to as many as possible of the older, non-insecticidal approaches to pest control as well as new methods that have emerged more recently. The aim has been to manipulate or manage pest populations by a combination of all available means, so that they remain below the level at which they cause economic damage—hence the term 'pest management'. Insecticides are integrated into the control procedures where their advantages outweigh their disadvantages, as they often do, but it is clearly desirable to make as much use as possible of methods that do not require the continuous energy input involved in insecticide manufacture and application. Such methods are not without their own problems in the transition from complete reliance on broad spectrum pesticides to a more selective usage and at minimal dose rates necessary to produce the required result. Finally, it is important to recognise a major change that has occurred over the past 25 years. This is the extremely high (perhaps unnecessarily high) standard of freedom from insect damage that is now demanded by consumers, a standard that is far less readily achieved by non-chemical measures.

A few of the interesting projects being undertaken by Australian entomologists are described in the following thumbnail sketches, the brevity of which should not be allowed to conceal the very large effort involved in the necessary detailed studies of the ecology, population dynamics, taxonomy, physiology and behaviour of the species concerned.

Cattle Tick

Boophilus microplus is a serious pest in tropical and subtropical Australia, where it infests some 9 million cattle and causes losses probably exceeding A\$40 million per annum.* Until 1947 the only control practised was to dip cattle in vats containing an arsenical solution, but a new era dawned with the advent of DDT and its use became widespread and even mandatory in areas where arsenic-resistant ticks had become a problem. A little more than a decade later the use of DDT was prohibited when the residues in cattle tissues became unacceptable in overseas markets. Chemical control now depends on materials that leave low and less persistent residues. Meanwhile the tick has developed resistance to all of the materials that have ever been used against it for any appreciable period. Thus Queensland is infested by nine strains of ticks with various spectra of resistances to organophosphorus compounds and carbamates and there seems to be little prospect of any chemical remaining useful indefinitely.

To circumvent the problems of resistance and residues, considerable effort has been put into research to reduce or eliminate the use of acaricides. Two of the approaches have given particularly valuable results. (i) Studies on the duration of egg development and of the longevity of larvae waiting in the pastures for hosts showed that, although a few larvae survived for eight or nine months after the engorged parent female had fallen from the host, the majority perished within a month or so of hatching. Thus it is possible to avoid heavy tick infestations by a routine of 'pasture spelling'—vacating paddocks for periods long enough to ensure that most tick larvae have died—then restocking with cattle, which, if necessary, have been freed of ticks by dipping. Many fewer dippings are required under such a regime. (ii) The second, and by far the most valuable means of long term tick control, for it also helps to control tick fever, is the use of tick-resistant cattle. Prominent in this approach is the use of Asian breeds that have evolved in evolutionary association with the cattle tick and are resistant to tick infestation. Hybrids between such stock and European breeds make good beef animals and are often so inhospitable to ticks that dipping is unnecessary. Relatively tick-resistant animals also occur sparingly in several breeds of European origin and these have been selectively bred to produce tick-resistant herds without infusion of Asian blood, but the process is very much slower.

Sheep Blowfly

The attack on living sheep by maggots of *Lucilia cuprina* costs Australian producers at least A\$30 million a year. Infestations occur chiefly in the wrinkly crutches of merino ewes but also, when conditions favour the fly, on the shoulders and occasionally on other parts of the body. As with the cattle tick, chemicals have been used extensively for protection, but the fly has become resistant first to cyclodienes and, in more recent years, to organophosphorus compounds, and the problem of residues in carcasses limits the choice of alternative insecticides. Of older methods tried, biological control and trapping have proved to be of negligible value, and the destruction of carcasses ineffective because most of the *L. cuprina* population breeds on living sheep; susceptibility to both crutch and body strikes could be reduced by selective breeding, but nearly always at the cost of fleece production; and the one economically practicable method that would give almost complete, life-long protection from crutch strike—surgical removal of

*A\$1=£0.62.

wrinkles and correct docking of tails of young lambs—has failed to find the extensive favour among graziers that it deserves. Clearly, a new approach is needed.

In spite of the cost of the fly to the sheep industry, the cost-benefit ratio of a sterile male eradication programme, such as has been successful against the screw-worm fly in parts of the United States, is highly adverse on account of the huge area (more than one-third of Australia) infested by the pest. A cheaper method is now being investigated—the production of synthetic strains of flies with chromosomes rearranged so that they are incompatible with the chromosomes of 'wild' flies, with the result that any crosses produce non-viable progeny. Extensive genetical studies that have already been done in the laboratory show that *L. cuprina* is well suited to this approach.

Sirex Wood Wasp

Pinus radiata is by far the most important plantation softwood in Australia. In the middle forties a consignment of infested pine logs from New Zealand led to the establishment of a European wood wasp (*Sirex noctilio*) in stands of this pine in Tasmania and Victoria. Although *Sirex* wasps are of minor significance in Europe, except when pines become unthrifty or are damaged, this wasp killed many trees in New Zealand and 40% to 50% in the early years after its establishment in a plantation near Hobart.

Sirex noctilio females commonly drill several tunnels into the timber at each oviposition site, in the process introducing a toxic mucus produced in a special gland. Even minute quantities of this mucus produce a severe, temporary setback to the tree, reducing its capacity to wall off *Sirex* eggs and the associated fungus (*Amylostereum areolatum*), known only from trees into which *Sirex* has inoculated it during oviposition. Its metabolites are capable of killing the pine tree. Initially, the rapidly growing fungus helps to produce conditions in the wood suitable for the development of the newly hatched *Sirex* larva and continuity of transmission is ensured by the female taking up a fungal culture into a special pouch, the mycangium, when she emerges from the pupal skin.

Wasp parasites of the egg or young larva (*Ithalia* spp.) locate their hosts by detecting the short chain metabolites produced by the young fungus. Later a different group of wasps (*Megarhyssa* spp., *Rhyssa* spp.) locate the larger larvae deeper in the trunk by different metabolites produced by the older fungus and associated micro-organisms. Success has been realised in establishing in Australia eight wasps from various regions of the northern hemisphere, including regions where *S. noctilio* does not occur, because they use the same fungal metabolites to locate their prey. In regions of Tasmania where the complex of parasites has been longest established, attack, especially by *Megarhyssa nortoni* (Fig. 1), now exceeds 75%.

More recently, a nematode (*Deladenus siricidicola*) has also been established. Eggs of nematode-infected *S. noctilio* females consist of a chorion packed with juvenile nematodes. After oviposition these juveniles escape from the egg and enter a free living phase, feeding exclusively upon the *Sirex* fungus, moving extensively through the timber, and passing through many successive cycles of multiplication. If these free-living forms locate a *Sirex* larva, infective forms are next produced which penetrate the *Sirex* cuticle. They multiply prolifically shortly after pupation and pack into the developing eggs of the female. Most of the *S. noctilio* emerging from nematode-infested trees contain *D. siricidicola*. It is expected that the combined attack of the nematodes and the parasitic wasps will reduce the major threat that was posed by *S. noctilio* and will result in a level of attack similar to that in the northern hemisphere. The intricate relationship between the *Sirex* wasp, its specific fungus and the *Sirex* parasites is indeed unusual.

In addition to biological control, various silvicultural means have been adopted to reduce susceptibility of the pine trees. These include the selection of sites where the pines will grow vigorously, avoidance of pruning during the *Sirex* flight season, and programmed thinning to keep the trees growing vigorously.

Orchard Mites

Organophosphorus insecticides, such as azinphos methyl, give excellent control of codling moth (*Cydia pomonella*) in apple orchards in south-eastern Australia, but they produce another spectacular effect, namely the release from predator control of the two-spotted mite (*Tetranychus urticae*) which causes severe damage to the apple leaves, necessitating the application of acaricides. A predatory phytoseiid mite (*Typhlodromus occidentalis*), resistant to azinphos methyl, was introduced from the United States and is giving excellent control of the two-spotted mite in sprayed orchards.

Skeleton Weed

Skeleton weed (*Chondrilla juncea*) is an extremely serious weed in wheat fields in south-eastern Australia. Its roots penetrate deep into the soil and pieces broken off by cultivation are each capable of producing a new plant. A flat rosette of leaves is formed in autumn which grows until early summer and then produces one or more tough, flowering stems. The early growth of the weed in wheat fields rapidly depletes the surrounding soil of available nitrogen and moisture, thereby suppressing nearby wheat plants. Later the wiry stems interfere seriously with harvesting machinery. The yield of heavily infested fields can be reduced from 30 bushels per acre to 15 or less and annual losses are estimated to exceed A\$30 million.

Skeleton weed is widespread in the Middle East and Mediterranean areas, but it is a relatively uncommon plant and is hardly ever regarded as a weed. It is heavily attacked by many organisms, none of which were present in Australia when investigations commenced in 1966. Seven insects, an eriophyid bud mite and three fungi have been studied. Most destructive of the fungi was the widespread rust, *Puccinia chondrillina*, which kills young *Chondrilla* seedlings and severely damages older plants. Extensive testing of this rust against all of the plants of substantial agricultural importance to Australia demonstrated that it was entirely specific to *Chondrilla* and was quite unable to develop on other closely related Cichoriaceae. Rust spores were released in Australia in 1971, constituting the first example in the world since the establishment of effective quarantine controls, of the deliberate introduction into a new country of a plant pathogen for weed control. The rust spread spectacularly and, in less than a year, could be found infesting plants in virtually every stand of skeleton weed examined in Australia. Very extensive

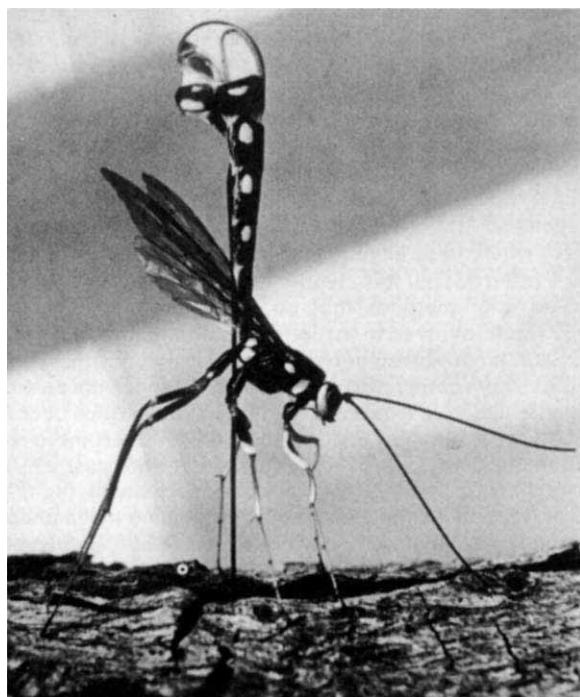


Fig. 1 *Megarhyssa nortoni* drilling in a pine log.

damage to the stems of skeleton weed plants has already occurred over vast areas, in many instances stems dying back to ground level before flowering. Vast numbers of young rosettes have also succumbed to attack. Five other organisms have so far been demonstrated to be specific to skeleton weed. Of these a gall fly, a stem-boring moth, and a bud mite have also been imported. The use of a bud mite for biological control also breaks new ground.

Potato Moth

The practicality of using an insect pathogen in lieu of an insecticide was demonstrated in large-scale field experiments against the potato moth (*Phthorimaea operculella*). A specific granulosis virus of the moth larvae was discovered and sufficient infective material accumulated to spray commercial crops of potatoes in Western Australia. One virus application at the beginning of the season was compared with the usual regular application of insecticides throughout much of the growing period of the crop. Tubers from the virus-sprayed crops were virtually free of potato moth damage, whereas there were quite high levels of damage on unsprayed crops and on some of the crops treated according to normal spray schedules. A single application of virus gave protection that equalled the best provided by insecticides. Virus-infected larvae were also discovered on untreated plots up to several miles away and insectivorous birds were found to be spreading the virus which appears to be comparatively resistant to environmental degradation. Problems of mass production and of registration as yet prevent the general use of this pathogen in commercial potato growing.

Dung Beetles

Although Australia has indigenous dung beetles adapted to dispose of the pellet-like droppings of its native herbivores, the marsupials, these beetles have negligible impact on the large dung pads of introduced cattle. Such dung pads soon dry into a hard cake where they have fallen on the pasture, many remaining substantially unchanged for months or even years. By comparison, in countries such as Africa where large herbivores evolved, the dung pads are frequently buried by beetles within a day. Bovines each produce ten or more pads a day, which continue to smother pasture until they are dispersed. Furthermore, around the periphery of each pad there develops a rank growth of pasture which cattle will not eat. In this way each bovine is capable of alienating a fifth of an acre each year and the extent of the loss can be measured by considering that there are some 30 million cattle in Australia. As well as rendering useless up to 6 million acres of pasture each year, the pads are the major breeding ground of two nuisance flies, the blood-sucking buffalo fly of cattle in the tropics and the widespread, pestiferous bush fly which worries man and other animals.

An active programme is in progress to re-establish in Australia the ecological balance whose disruption commenced



Fig. 2 *Sisyphus rubripes* rolling its dung ball.

almost two centuries ago when cattle were introduced by the First Fleet. African beetles are being introduced, using specially developed methods involving the utilisation of surface-sterilised eggs in order to prevent the introduction of any undesirable fellow travellers or diseases. Beetles of one type work in the soil directly beneath the dung pad, constructing tunnels into which they carry dung which they form into balls containing their eggs. Another type (Fig. 2) fashions dung balls which are rolled for some distance over the surface of the ground before burying. These activities reduce fly breeding and, also greatly reduce the survival of helminths hatching from eggs passed out in the dung. Some twenty beetle species have already been introduced, but it is believed that more than 100 will be required to deal with dung in all the various climatic and other environmental conditions where cow pads are abundant. Fortunately there are some 2,000 species in Africa south of the Sahara to choose from. In the 6 years since it was first liberated, one species (*Onthophagus gazella*) now buries dung pads completely in a day or so in tropical areas during the rainy season, and similarly spectacular results are being obtained with another species in northern New South Wales. If an adequate range of dung beetles is established in Australia an annual return worth many millions of dollars will unquestionably result.

In many problems, including some of the foregoing, pesticides still have a valuable role to play, but the increasing use of resistant varieties, parasites, insecticide-resistant predators, nematodes, viruses, fungal pathogens, cultural modifications and other means are all contributing to saving tens of millions of dollars each year and the prospects for further profitable extension of use of such methods are very bright indeed.

Solar Power in the Australian Energy Scene

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Dr Morse discusses the most cost effective ways of utilising solar energy in Australia and points out the possibilities of producing 'synthetic' liquid and gaseous fuels from trees and plants.

THE primary energy pattern in Australia is undergoing a very significant change due mainly to the discovery in 1966 in Bass Strait of oil and gas in commercial quantities. Prior to that the search for oil had been going on for a long time with some minor successes, but it was the Bass Strait strike which stimulated the exploration drilling which in due course led to a number of widely separated discoveries. Although these are mostly natural gas, Gidgealpa in Central Australia and the North Rankin field on the north-west

shelf off the West Australian coast will have a big influence on the national energy pattern.

Known reserves are sufficient to ensure a very important role for natural gas for the next 50 yr. Melbourne and Adelaide are already being supplied by pipelines from the Bass Strait and Gidgealpa fields respectively, and the Government has set up a Pipeline Authority to acquire and distribute petroleum products throughout Australia. It is at present arranging contracts for the pipeline to supply Sydney from the Gidgealpa field and is investigating the feasibility of supplying Perth, Kalgoorlie and the Pilbara.

The Department of Minerals and Energy's forecast, dated August 1973 (ref. 1) for fuel consumption in 1984-85 is given in Table 1. During the period 1972-73 to 1984-85 natural gas consumption is expected to increase at 18.9% a year and by 1985 it will be supplying about 10^{18} J yr⁻¹. At this rate of consumption, published reserves will be exhausted by the year 2020.

Table 1 Forecast of Australian Energy Consumption

Fuel	Percentage of total		Annual usage J $\times 10^{-18}$	
	1971-72	1984-85	1971-72	1984-85
Petroleum products	49.5	41.8	1.111	2.166
Black coal	29.8	26.5	0.669	1.374
Brown coal	10.6	10.4	0.237	0.540
Natural gas	4.5	18.5	0.102	0.956
Bagasse	2.0	1.2	0.045	0.060
Hydroelectricity	1.9	1.1	0.042	0.058
Wood	1.7	0.5	0.038	0.023
Total	100	100	2.244	5.177

Indigenous oil reserves are much less and according to recent announcements by the Minister for Minerals and Energy will be exhausted in about 8 yr. Imports of liquid petroleum products, which are at present about one-third of the total, can therefore be expected to increase steadily during the next decade unless there are new discoveries. Since these account for nearly 50% of Australia's present primary energy requirements, this situation has far-reaching implications. More than half is used for transportation, which has become increasingly dependent on liquid fuel. It is expected that in the near future about one-third of the nation's total primary energy will be used for transportation, most of which is required in the form of liquid fuel.

Australian coal reserves are very large and provide the primary energy for 75% of the country's electric power production, the remaining 25% being hydroelectric. Since future hydroelectric development will be limited, the nation's electric power system will become increasingly dependent on thermal stations operating on both black and brown coal. A natural gas-fired power station is planned for Melbourne but there are no nuclear power plants either in operation or under construction.

A summary of known recoverable energy sources prepared by George³ is given in Table 2, with some updating for natural gas. The enormous energy recovery from uranium using breeder reactors has focused attention on the problems of nuclear power generation, particularly the difficulty of disposing of radioactive wastes. The risk of

irreversible genetic damage to plant and animal life on a large scale has stimulated the study of alternative power sources which have a low environmental impact.

A comparison of the numbers in Tables 1 and 2 shows that Australia has ample reserves of both black and brown coal to supply its power stations for a very long time to come and is therefore in the fortunate position of being able to defer a decision on the introduction of nuclear power until the waste problem has been satisfactorily solved.

In the meantime there is growing interest in the development of renewable energy sources which are 'clean'. The ultimate hydroelectric development is about double the present capacity. The tide range of the north-west coast, extending about 1,000 mile west of Darwin, is typically 10 to 12 m, which has provided the basis for suggestions that tidal power could have a large potential in this area. Wind power may have useful applications on a small scale in specific areas but is most unlikely to make a significant contribution on a national scale.

Solar Power

There is, however, now widespread recognition of the potential of solar energy as a future major power source for Australia, and some of the implications were considered at a UNESCO symposium in Adelaide in May 1973 (ref. 3). A Committee appointed by the Australian Academy of Science has suggested targets for the contribution of solar energy to the nation's primary energy needs and recommends a substantial programme of research⁴.

Already there is a small but efficient solar water heating industry producing well engineered absorbers, and about 20,000 m² have been installed throughout the country. They provide heat at about 60° C and are suitable for manufacturing, commercial and residential applications. This industry is backed by a research programme in the CSIRO's Division of Mechanical Engineering and several of the Australian universities, which have been studying the use of solar energy in the form of heat at low temperatures. This work is being extended to include applications up to about 120° C, embracing the industrial use of low pressure steam. It seems that the heat required at these temperatures accounts for about one-third of the total primary energy used and is the most promising area for solar energy utilisation at the present time.

Solar energy is widely and fairly evenly dispersed and is generally available where it is needed without reticulation. The annual insolation on a horizontal surface does not vary very much throughout Australia (Fig. 1). The Simpson Desert, for example, collects only about 30% more solar energy than Melbourne. Places near the Equator have the advantage, however, that variations in insolation from season to season are small, so that solar-powered devices can operate more efficiently. For Darwin, latitude 12° S, the mean daily insolation collected on an inclined surface in the best month is only 40% more than the worst month, whereas for Melbourne the difference is 120%. This means that solar water heaters in Darwin can operate satisfactorily without fuel or electric boosters but in Melbourne they cannot.

Solar radiation consists of a direct and diffuse component. Diffuse radiation is due to scattering in the Earth's atmosphere, and arrives on a horizontal surface approximately uniformly from all directions in the sky. It is typically between 20 and 40% of the total energy received in a year and this is lost when solar energy is concentrated by a focusing collector. The popularity of the flat plate absorber is due to its simplicity and its ability to collect both diffuse and direct radiation in a fixed position. Concentration can only be justified when high temperatures are required, and it seems that the most effective way of using solar energy is to collect and use it at low temperatures.

Table 2 Summary of Australia's Known Recoverable Energy Resources

		Gross energy equivalence J $\times 10^{-18}$
Black coal	12,601 million ton	300
Brown coal	20,000 million ton	200
Oil	2,110 million barrels	10
Natural gas	34×10^{12} foot ³	36
Uranium	142,000 short ton	60
	or with breeding	6,000

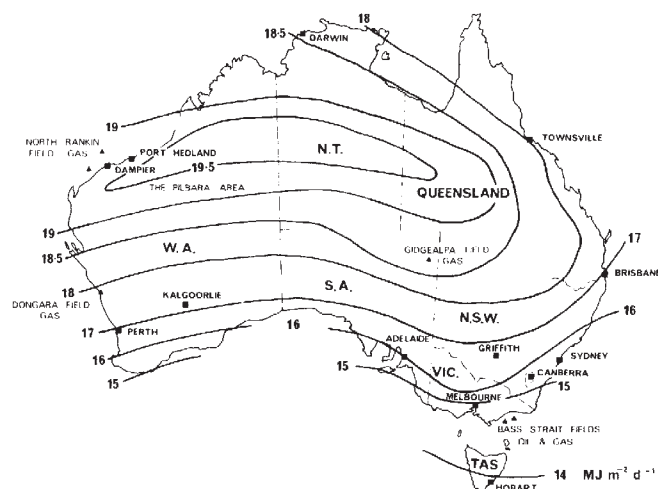


Fig. 1 Average daily solar radiation on a horizontal surface over Australia. Source: CSIRO Divisions of Atmospheric Physics and Mechanical Engineering.

A well designed commercially produced solar water heater², comprising absorbers and insulated storage with thermo-syphon flow connections, has an overall efficiency of 40%, expressed as the ratio of the annual quantity of heat available in the tank to the total radiation incident on the absorber over the same period. This is remarkably high compared with, say, a silicon cell (18%) and photosynthesis in plants (0.5%). It illustrates a basic characteristic of effective solar energy utilisation, which is that special purpose devices are used to perform specific functions, for example, water heating, desalination, drying and electric power. It would be very wasteful, for example, to generate electric power at 10% collection efficiency, feed it into a distribution network and then use the electricity to heat water.

It is now widely accepted⁴ that the most immediately effective way in which solar energy could supply some of the nation's energy needs would be in the form of low grade heat at temperatures up to about 120°C, and that research and development are needed to improve the cost effectiveness of installations for domestic, industrial and process water heating, house, factory and office heating, food processing, drying, desalination and possibly comfort cooling.

The cost effectiveness of a solar installation can be expressed as a figure of merit or a return on investment due to the value of the fuel saved, and techniques have been developed to optimise this⁶. It is dependent on many factors, including fuel cost, temperature at which the heat is required, and the proportion of the annual heat requirement which is to be met by solar energy. In general terms, the return on investment is high at low collection temperatures and where the percentage solar contribution is low, and decreases for higher temperatures and high percentage solar contribu-

tion. Accordingly the most attractive way to utilise solar energy now may well be to install solar absorbers sufficient to supply 20 to 30% of the annual fuel needs, and subsequently increase the collection area as fuel costs rise and so maintain a gross return of, say, 15% per annum on the solar investment. There are, however, favourable situations, such as Darwin, where a 100% solar water heating system at 55°C can return 30% per annum on the solar investment. Generally it will be necessary to use a solar plus fuel-boosted system to achieve an acceptable figure of merit.

Although solar energy can reduce the community's dependence on liquid petroleum fuels where these are producing low grade heat, by far the most important use of liquid fuels is for transportation. Here there is the intriguing possibility of the production of a synthetic fuel from cellulose, which can be considered as solar energy which has been stored in trees and plants. Both liquid and gaseous fuels can be produced from cellulose and other plant material by known processes. These processes have not yet been used on a large scale and considerable research and development will be needed before their practicability can be evaluated. It seems, however, that an area of 5×10^6 ha, that is, less than 1% of Australia's land area, would be adequate to provide 10^{18} J yr⁻¹ as a liquid fuel on a perpetual cycle. In this way the CO₂ which is produced when the fuel is burnt is recycled by photosynthesis in the plants. This is such a challenging objective that it is sure to be studied in considerable detail.

The generation of electric power from solar energy using photovoltaic, thermoelectric or thermodynamic processes is a less attractive proposition than either the low grade heat or synthetic fuel applications. It suffers both on the score of cost effectiveness and technological feasibility. There are no practicable large scale solar electric power plants in operation or even in sight at present. Australia's large coal reserves will defer the need for alternatives to conventional power generation for a considerable time. Photovoltaic devices, like the silicon cell at present very expensive, should drop substantially in cost over the next two or three decades, and may well be suitable for use in isolated areas where reticulation from central power stations is inherently costly. In fact, this could be one of the long term advantages of solar energy: its availability where it is required without reticulation.

It has been suggested⁴ that by the year 2000 solar energy could be an important primary energy source for Australia, providing 10^{18} J yr⁻¹ in the form of low grade heat and another 10^{18} J yr⁻¹ as synthetic fuel. If this is to be achieved it would involve the creation of a major new industry, as well as substantial research and development by government, academic and industrial laboratories. It is not possible to say yet whether the economic incentives resulting from the anticipated cost increase in naturally occurring fuels will be sufficient to bring this about, or whether it will be necessary or even desirable to introduce other incentives. The prospect, however, of a quarter of Australia's primary energy coming from a renewable source within 30 yr is one which has to be taken seriously.

¹ *Forecast Consumption of Primary Fuels 1972/73 to 1984/85* (Fuels Branch, Department of Minerals and Energy, Melbourne, 1973).

² George, D. W., *Energy resources and usage*, Charles Kolling Research Laboratory Technical Note ER-2 (University of Sydney, 1973).

³ Morse, R. N., *Proc. UNESCO Man and the Biosphere National Symposium on Energy and How We Live* (Flinders University, Adelaide, 1973).

⁴ *Report of Committee on Solar Energy Research in Australia* (Australian Academy of Science, 1973).

⁵ *Solar Water Heaters—Principles of Design, Construction and Installation*, CSIRO Division of Mechanical Engineering Circular No. 2 (1964).

⁶ Morse, R. N., Davey, E. T., and Welch, L. W., *High temperature solar water heating*, paper EH60, *Proc. int. Cong. "The Sun in the Service of Mankind"* (Paris, July 1973).

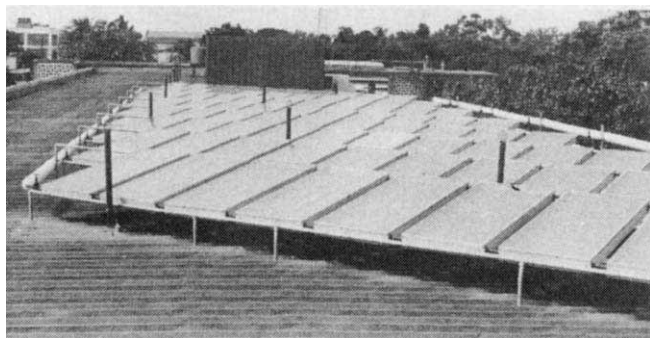


Fig. 2 Solar water heating installation on the roof of the Esplanade Hostel, Darwin.

Rock Art in Australia

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A national programme of recording of Aboriginal rock art sites has been accepted by the Australian Institute of Aboriginal Studies as one of its principal research priorities.

ABORIGINAL rock art in Australia has engaged the interest of European explorers and settlers since they arrived in the continent in 1788. Many of the observations made, and questions asked by them, remain as pertinent today as they did then. For example, Grey¹ was concerned with establishing dates for the art which he found in the Kimberleys: "With regard to the age of these paintings, we had no clue whatever to guide us. It is certain that they may have been very ancient, for although the colours were composed of such perishable materials, they were all mixed with a resinous gum, insoluble in water, and no doubt, when thus prepared, they would be capable of resisting, for a long period, the usual atmospheric causes of decay. The painting which appeared to me to have been the longest executed was the one clothed in the long red dress, but I came to this conclusion solely from its state of decay and dilapidation, and these may possibly have misled me very much".

In addition, the early history of the discoveries, and the statements made by the first Governor of Australia, Arthur Phillip², could, and we believe should, have had a profound impact on the doubtful assumptions and assertions made in connection with the acceptance of some rock art of prehistoric Europe as archaeologically ancient and as the work of hunters and gatherers. In 1788, within 3 months of setting foot in Australia, Phillip, while on one of his first explorations near Sydney, found a series of rock carvings. He wrote²: "... in the neighbourhood of Botany Bay and Port Jackson, the figures of animals, of shields, and weapons, and even of men, have been seen carved upon the rocks, roughly indeed, but sufficiently well to ascertain very fully what was the object intended ... that the arts of imitation and amusement, should thus in any degree precede those of necessity, seems an exception to the rules laid down by theory for the progress of invention. But perhaps it may better be considered as a proof that the climate is never so severe as to make the provision of covering or shelter a matter of absolute necessity". In Europe, it took from 1878 to 1902 for scholars to accept the great antiquity of Palaeolithic art and thus, implicitly at least, to overcome the generally held assumption that hunters and gatherers could not have had the time, and were by definition, incapable of producing art works³. Even as late as 1966 the main message emanating from an international conference⁴ on hunters and gatherers was that foragers were not totally preoccupied with the quest for food. In Australia there has never been any doubt that hunters and gatherers had the time, capacity and motivation to carry out works of art.

Overall, the work of the early explorers and colonisers of Australia, in so far as it concerned Aboriginal culture and rock art, was largely objective recording and description and, at the same time, showed a depth of enquiry and perception well ahead of much scientific enquiry in other continents concerned with hunters and gatherers.

Acute descriptions, such as those of Grey¹ in the Kimberleys—"Each of the four faces was marked by a totally

distinct expression of countenance, ... although none of them had mouths ..."—and King⁵ on Clack's Island—"They were executed upon a ground of red ochre and were delineated by dots of white ... earth (and) decorated all over ... in dotted transverse belts"—serve to distinguish different Aboriginal rock art styles.

Distribution and Age

During the late nineteenth century enlightened amateurs carried on sporadic recording and observations. No significant advances regarding the identification of stylistic variation in Aboriginal art took place; indeed the assumption of the time was, as Mathews⁶ wrote: "Aboriginal drawings are almost everywhere of the same character, with but little variation either in the subjects treated or in the style of workmanship." The main change in approach to the systematic analysis of Australian rock art started with the impetus of the ethnographic recording of Spencer and Gillen⁷. Their work placed emphasis on the material culture and rich ceremonial of Aboriginal life, and focused attention on the contemporaneity of Aboriginal culture. Basedow's work⁸ provided a corrective to the synchronic study of Aboriginal culture and art: "The conclusion is that some of the Australian designs must, upon this evidence alone, be regarded as extremely old." Basedow, in addition, reviewed a large body of material in order to reach conclusions about Aboriginal rock art styles and techniques. This approach continued in the work of pioneers of the scientific study of Australian rock art such as Mountford⁹, Davidson¹⁰ and McCarthy¹¹.

Much of the work of the authorities just mentioned took place during the time that archaeology began to develop in its own right. Research of this kind aimed at both detailed recording of rock art sites, the widening of knowledge of the geographic distribution of Aboriginal art works and the definition of 'styles', and more particularly techniques. McCarthy¹², in addition, initiated the numerical expression of the contents of the elements making up Aboriginal rock art. Such work, undertaken by a few dedicated people at a time when the analysis of rock art was not recognised as part of

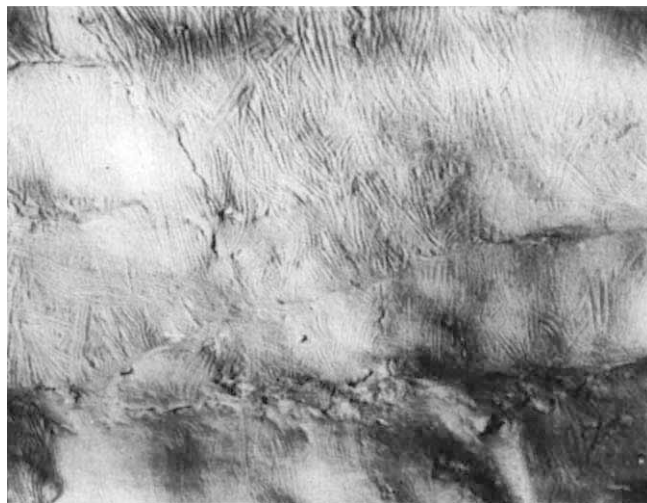


Fig. 1 Finger marks on the soft wall surfaces in Koonalda Cave, South Australia.

academic university studies, formed the basis of research on Australian Aboriginal art until a few years ago.

During the past ten years or so the picture regarding not only the wide distribution and the complexity of styles but also the antiquity of Aboriginal rock art has changed fundamentally. The first possible indication of the real age of rock engravings came as early as 1929, with the discovery¹³ of abraded grooves on the back wall of the Devon Downs rock shelter on the lower River Murray at a depth of between 3 and 4 m below ground surface. It was not until 1966, however, that a positive date was obtained for engravings. The site was a shelter adjacent to the permanent Ingaladdi waterhole on Willeroo Station in the Northern Territory. The walls of the sandstone outcrop were covered completely with engravings and paintings. Many engravings were weathered and strongly patinated, but others, including one of a ship, were obviously of recent origin. Detached rock fragments bearing engraved bird and animal tracks and abraded grooves were found in the main excavation trench. These engraved pieces were recovered between levels radiocarbon dated to $4,920 \pm 100$ BP and $6,800 \pm 270$ BP¹⁴.

A year later, at Koonalda Cave on the Nullarbor Plain in South Australia, charcoal from a passage deep down in the cave yielded a date of about 20,000 BP¹⁵. The charcoal could have come from crude torches used by prehistoric man, who came to the cave to mine flint. For the first time in Australia, a site contained evidence of artistic activity carried out in total darkness inside a deep cave. The 'art' consisted of finger impressions (Fig. 1) in the soft and friable walls, and incised lines abraded or scratched into the harder surfaces. Although there was no direct association between engravings and charcoal, the fact that large areas of engravings were found in a cavity 15 m below a rock fall confirms the 20,000 yr date for the art¹⁶.

Rock engravings in Tasmania had been known since the 1930s, but it is only very recently that new sites have revealed the extent of this art form and provided an adequate sample for comparative analysis. The engraving technique used is



Fig. 2 Drawings made by Grey in 1838 of Wandjina cave paintings in Western Australia.



Fig. 3 Kangaroo painted in X-ray style with backbone and internal organs depicted, Arnhem Land.

identical to that found over a wide area of the mainland and the motifs also are known from many sites. It seems likely that these similarities are evidence for a common artistic tradition between Tasmania and other parts of Australia. If this is so the art must date back to a period of at least 12,000 yr, before the time that Tasmania was separated from the mainland¹⁵.

In assessing the antiquity of painting in rock shelters unfortunately one has to rely on the dating of ochre found in excavation deposits. Ochre pieces with ground facets have been found in many sites, extending back some 19,000 yr at Kenniff Cave and two sites in Arnhem Land and 30,000 yr at Mungo¹⁵ (and personal communication from D. J. Mulvaney and J. Kamminga). If the ochre was used for rock art as well as for body painting and decoration of material objects it would seem that rock paintings had at least as great an antiquity as rock engravings. Rock art in Australia is therefore at least as old as art anywhere in the world.

Styles of Art

The analysis of rock paintings has focused mainly on the definition of styles and the recognition of artistic regions. The Wandjina figures (Fig. 2) of the Kimberleys of Western Australia¹⁷, unique in terms of their large size, absence of mouths and various other attributes, remain, as already noted by Grey¹, distinctive and restricted geographically.

X-ray art, first described in Arnhem Land by Spencer¹⁸ in 1912 (Fig. 3), is a particular art form through which the Aborigines portrayed features in excess of those which are externally visible; X-ray art is now known to extend at least throughout the whole of Arnhem Land. Another identifiable form is the so-called *Mimi* art of Northern Australia¹⁹ in which human 'stick' figures are depicted with attenuated limbs and are usually shown full of animation. In the centre of Australia the engravings and paintings are based on a restricted repertoire of lines, circles, tracks and geometric motifs²⁰. Over most of south-eastern Australia the art is concerned with the depiction of small anthropomorphic representations²¹.

The recent discoveries by Trezise²² of the vast art complexes of the Laura area of Cape York in Queensland have revealed a distinctive complexity and richness of representations of local flora and fauna, artefacts and anthropomorphic and other beings, hitherto unsuspected in the continent of Australia. Some paintings in this region could date back 10,000 yr, as ground ochre was found throughout a deposit in a decorated rock shelter²³. Stencilling¹¹, at least of hands, seems to be present throughout Australia; stencils of feet and objects of material culture may have been more limited geographically (Fig. 4).

The vastness of the Australian continent, the inhospitable nature of much of the terrain and the real practical difficulties of carrying out field work, explain in part what is perhaps the chief reason for the incomplete nature of knowledge of the distribution and characteristics of Aboriginal rock art.

Present and Future Research

During the past ten years or so some 100 decorated new sites have been found. As a consequence of the increasing realization of the importance of adequate scientific recording of Aboriginal art and of the major significance attached to various of these sites by living Aborigines, a national programme of recording has been initiated by the Australian Institute of Aboriginal Studies. Some twenty fieldworkers have been employed on a full-time basis for an initial 5 years in order to plot and record art sites throughout the continent. A growing realisation of the importance of Aboriginal art in the world context, and equally of the complexity of adequately documenting it, has led the institute to accept as one of its major research priorities the analysis in depth of Australian rock art sites. What is envisaged is the cooperative undertaking, by international experts, of the recording of particular rock art sites or areas of artistic activity, with a view to:

- The documenting, with the aid of Aboriginal informants, of the reasons and influences which underlie current artistic activity.
- The recording of Aboriginal rock art sites in the greatest detail possible.
- The precise definition and analysis of styles, content and antiquity of Australian rock art.
- The quantitative recording of the content of the art.

Techniques, such as photogrammetry, which for practical reasons in the context of European Palaeolithic art inside deep caves have proved unsuitable, have just begun to be used in Australia for recording the art in rock shelters.

Interest in the study of Aboriginal rock art has, for many decades, been focused on its relevance to prehistoric art in other continents³. It is clear that this orientation should not be

the sole reason for such research and analysis, but nevertheless there is no doubt that the Australian situation is unique as, in some regions, Aborigines continue not only to value their rock art sites but also to maintain their artistic activities and, where appropriate, their associated ritual. Immediate research in Australia will focus on documenting the 'explanations' and details which Aborigines are able to give regarding their rock art.

In 1895 Mathews²⁴ wrote: "The painted and carved rocks of Australia, the handiwork of the Aboriginal inhabitants, are widely scattered over the continent, and it is a matter of surprise that a subject of so much interest and value to anthropologists should have been so long neglected by scientific men, and others, competent to deal with them. It is greatly to be deplored that these drawings received so little attention from early settlers in the Australian colonies, who must have had numerous opportunities of observing them, and that no efforts were at that time made to record and preserve these specimens of pictorial art, showing the imitative and inventive faculties of a primitive people"—sentiments to be echoed no less today.

The challenge to current fieldworkers is highlighted by the fact that some individuals are continuing to decorate rock surfaces and that different groups of Aborigines are returning to their lands and have revived, or are about to begin to renew, the painted art of the rock shelters. Part of the challenge for the future of the study of art in Australia is to be allowed the privilege of witnessing and recording the return to this fundamental activity. It is not long ago that rock engraving was a living art form; in the present context of Aboriginal activity, the decoration of rocks in general may survive.

Further research must also concentrate on the scientific analysis of tool marks left in the engraved designs and also on a search for tools at the engraved and painted sites. Only in this way can it be shown whether or not the artists had specialised tools devoted to engraving and what sort of activities were carried out at these sites.

Calculations of the relative frequencies of the occurrence of designs and subject matter are currently in progress²⁰. They will serve to distinguish individual from 'group' activity and will also provide a more secure basis for the objective assessment of local or regional definition of rock art areas. At present it seems that in engraved rock art sites, animal tracks and circles are represented much more frequently than all other items. Studies of orientation, relative size, complexity of figures and associations are also planned.

Work is under way to determine the physical factors contributing to the erosion and patination of rock surfaces, particularly with reference to the assessment of the length of time inherent in the formation of the various conditions which today characterise the visible rock surfaces of Aboriginal art sites and also with reference to problems of conservation. In some instances it is possible that the joint evidence of natural agents and Aboriginal attitudes towards their art and its renovation, may yield clues to the dating of particular art activity.

Another immediate priority for future research in Australia must be the attempt to date Aboriginal art activities scientifically. An important new aspect is that archaeological research is being directed to the investigation of the antiquity of art sites. Excavations will be carried out where it is likely that engraved or painted wall surfaces have been buried under habitation debris.

Priorities for research on Aboriginal rock art should be influenced by international work on similar material but they should also be determined by the particular characteristics of Australian art. An important problem is the extent, and the nature, of the factors which allow one artistic motif as opposed to another to be interpreted variously according to the operative social contexts^{25, 26}. Another problem common to studies of most rock art is the definition of 'naturalistic' and 'schematic' representations. In other parts of the world, so



Fig. 4 Stencil hands, a boomerang and stone axe, on the walls of a Carnarvon Range rock shelter, Queensland.

called schematisation has been taken as a chronological marker²⁷. Australia, with its unique opportunities for consultation with the artists concerned, as well as the time depth and complexity of the rock art, offers perhaps the best hope for the clear definition of such stylistic features.

International Significance

Not surprisingly, many of the methods of analyses, and approaches to the study of Australian rock art, are identical to those used in other areas of the world. Frequently it is not possible to prove a clear association between a work of art on a cave or shelter wall and a nearby archaeological deposit. For this reason, throughout the world, the dating of rock art has had to rely to a considerable degree on the content of the art. This is no less true of Australia where, today, much of the rock art has become archaeological material²⁸. Neither in terms of method, nor in resulting discussions, is there any difference between the way prehistorians and anthropologists have approached the identification of artistic depictions of tool and weapon types in different parts of the world. Similarly, the mammoth/elephant of the European Ice Age art and the dingo of Australian art have been seen to be critical for dating the respective rock arts and, in both cases, their positive identification in art has proved difficult. Imperceptibly, in the analysis of rock art, what seems to be a simple problem of chronology becomes a complex matter involving the observer's views regarding style and artistic licence. Furthermore, the possibility, in almost all rock art of the world, that some representations may refer to beings of mythical or 'monstrous' significance adds a further bewildering complication to the secure identification of specific representations which may be crucial for dating purposes. Dating of Australian art relies heavily on the correct identification of painted domesticated animals, guns, ships, Macassans, Chinese and Europeans.

Superpositioning of representations is again one which characterises much rock art throughout the world. There can be no doubt about the importance of the correct understanding of this practice, not only in terms of chronology but also for the understanding of the artistic activities involved in producing rock art and the interpretation of the significance of much of this art form^{3,28}. In this context there should be a general realisation, deriving from the recent analysis of European rock art by Leroi-Gourhan²⁹, of both the complexity and the extreme importance of the Australian evidence despite the fact that much of it is self-contradictory and ambiguous^{3,28}.

At first sight it is possible to list the unique qualities of content and context of Australian rock art, as compared with any other single body of rock art. But work has hardly begun on a rigorous attempt to define and make such comparisons precise and, as a result, the conceptual and analytical assumptions made in any comparative generalisations are naïve and unsystematic. It was not difficult, only a few years ago, when both the range and antiquity of the Australian material was unknown, to pinpoint the supposed difference between European Palaeolithic and Australian art; the first includes mobile art and a static parietal art concerned with animals and situated deep inside caves, and the second is without mobile works, has parietal works in the open air and is full of animated action. But to adopt such an approach is to ignore the variety of both European Palaeolithic art and the Australian evidence (for example, Palaeolithic art is found also in open air shelters and sometimes also apparently concerned with movement and action³, and Australian art now includes the evidence of Koonalda and is not uniquely concerned with scenic activities). Furthermore, almost no attempt exists at a rigorous comparison of the Australian material with the art of other hunters and gatherers; for example with the East Spanish Levantine material³², which is also an open air art of animated action.

To make meaningful statements about similarities and differences between the rock arts of different ages and widely separated areas demands fundamental re-analysis of existing material and rethinking of current assumptions about the nature of these art forms. Not the least of these concerns the significance of similar artistic modes of expression; these similarities range from 'simple' engraved lines, finger-traced meanders and hand stencils to the 'complex' X-ray representations of animals and fish. Such 'artistic parallels' should lead not only to a re-evaluation of current ideas about the likelihood and conditions under which 'simple' and 'complex' independent inventions take place, but also to a new debate about the legitimacy of regarding 'rock art' as a particular art form in its own right. Australia, with its 'living' complex of song, dance, music, ritual and rock art, offers a unique possibility to answer such questions. Furthermore, future analysis of the historical and functional relationship and interaction between Australian rock art and bark paintings, should be able to cast the first reliable light on the claim that rock art is a unique art form characterised by the artist's use of a static and 'given canvas' possessing its own particular natural qualities. Only when the answers to such problems and questions are known will it become possible to assess the legitimate 'limits of inference' to be drawn from the study and analysis of rock art.

We thank Jim Allen, John Mulvaney and Andrée Rosenfeld for comments on this paper.

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Emerging Picture of Pleistocene Australians

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Man was well established in Greater Australia between 25,000 and 30,000 years ago and by at least 20,000 BP was occupying almost all of the principal ecological zones of the continent.

WALLACEA, with its numerous water barriers, was the decisive geographical influence on the prehistory of man on the Australian continent. Not only did it stem his southwards thrust from Asia for many hundreds of millennia, but it also served to isolate those human migrants who eventually acquired the technology to cross it. The theme of Australian prehistory is one of vast cultural continuities in space and time, characterised by conservatism and punctuated only rarely by influences from outside. The continental island of Java, periodically joined to the Asian mainland during periods of low sea level, has a rich human fossil record which extends back to about 2 million years ago. Stone tools of Pajitanian type in association with several species of extinct elephantids have been found eroding out of the presumed middle or early upper Pleistocene deposits on the islands of the Philippines, Flores and Timor¹, showing that these animals and man had managed to cross some substantial water straits in ancient times. There remained only one more barrier, which even during low sea levels was never less than about 40 miles wide.

Antiquity

The present evidence for the antiquity of man on the Greater Australian continent, including New Guinea and Tasmania, is shown in Table 1, where I have listed the basal radiocarbon dates for twenty-eight sites which are the oldest in their respective 'regions'; their locations are shown on Fig. 1.

It can be seen that man was well established between 25,000 and 30,000 yr ago, the oldest unequivocal evidence being the 32,000 BP date from the sand lunette bordering Lake Mungo^{6,10,16}. Older data may come from the river terrace deposits at Keilor, but the situation there is complicated by disagreement as to whether or not some of the stone and bone finds were fashioned by natural agencies rather than by human hand^{5,8,13,17}. Nevertheless, some indubitable flakes have been recovered by Gallus and his colleagues from deposits which must be at least 30,000 yr old and are probably considerably older. All the results shown in Table 1 were gained during the past decade and the pace of discovery shows no sign of abating. While the search for older sites continues, the outlines of the prehistory of man in Australia during the past 30,000 yr is also beginning to emerge.

The Lake Mungo lady, securely dated to 25,000 BP, was fully sapient, with a gracile cranium that can be fitted within the morphological range displayed by modern Australoids^{10,18}. This find, combined with remains from Niah and perhaps Tabon, shows that modern *sapiens* types were present in the south-east Asian region 30,000 and more years ago. In Australia, other morphologically 'modern' skulls are those from Keilor and Green Gully¹⁰ dated respectively to about 15,000 and 8,000 BP showing continuity to recent times. The situation is, however, complicated by the discovery of the 10,000 yr old Kow Swamp series, the crania of which show remarkably archaic characteristics for such late population⁹.

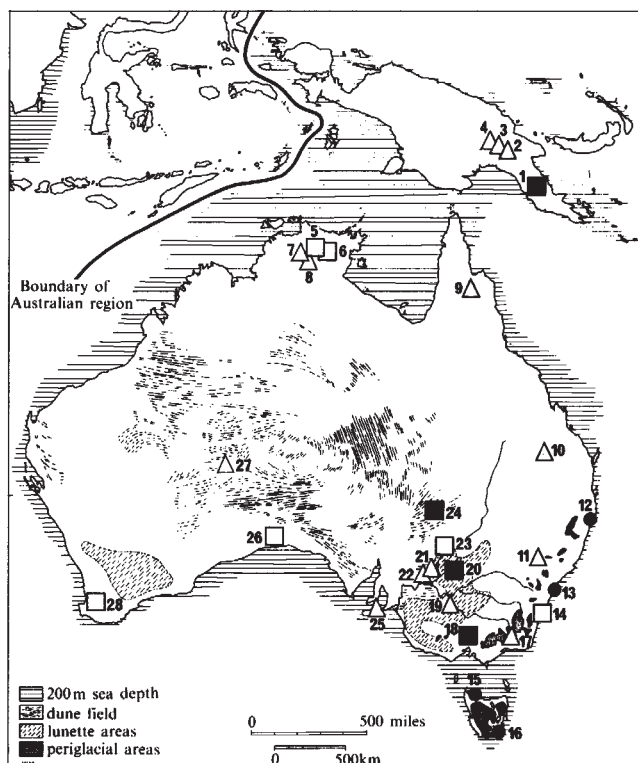


Fig. 1 Early man sites in Greater Australia. ●, Late Pleistocene; ●, 5,000-10,000; △, 10,000-20,000; □, 20,000-25,000; ■, 25,000-32,000 BP.

Many features of the facial region, such as the flat sloping foreheads, the supraorbital ridges and the massive mandibles, are reminiscent of *erectus* traits, and this tendency towards a robust form and a combination of archaic and modern features has been noted in several other late or post Pleistocene skulls such as Talgai, Cohuna, Mossiell, and Nitchie²⁰.

The co-existence of these two groups within the same relatively small area of south-eastern Australia during a period of presumably 20,000 or more years, requires an explanation

Table 1 Evidence of Prehistoric Man on the Greater Australian Continent

No. on Fig. 1	Site name	State	Type of site	Basal date of occupation BP	Laboratory No.	Material	Excavator	Further reference
1	Kosipe	TPNG	Open site, weathered volcanic ash	26,450 ± 880 26,870 ± 590	ANU-190 ANU-191	Charcoal Charcoal	J. P. White and B. P. Ruxton	2
2	Kafiavana	TPNG	Limestone rock shelter	> 10,730 ± 370	ANU-41b	Bone 'collagen'	J. P. White	3
3	Kiowa	TPNG	Rock shelter	10,350 ± 140	Y-1366	Charcoal	S. Bulmer	3, 4
4	Yuku	TPNG	Limestone rock shelter	> 9,780 ± 150 (top of deposit)	ANU-358	Charcoal	S. Bulmer	3
5	Malangangerr	NT	Sandstone rock shelter	24,800 ± 1600	ANU-77a	Charcoal	C. White (née Shrire)	4, 5
6	Nawamoy	NT	Sandstone rock shelter	22,900 ± 1000	ANU-77b	Charcoal	C. White (Shrire)	4, 5
7	Malakunanja II	NT	Sandstone rock shelter	21,450 ± 380	ANU-51	Charcoal	J. Kamminga	Personal communication
8	Linoner site	NT	Sandstone rock shelter	18,040 ± 320	SUA-265	Charcoal	J. Kamminga	Personal communication
9	Laura	Q	Sandstone rock shelter	> 19,900 ± 280	SUA-237	Charcoal	J. Kamminga	Personal communication
10	Kenniff Cave	Q	Sandstone cave	> 6,870 ± 150 (half way down deposit; base probably 10,000)	I-1735	Charcoal	R. W. S. Wright	4, 5
11	Noola	NSW	Sandstone rock shelter	18,800 ± 480	ANU-345	Charcoal	D. J. Mulvaney	5
12	Seelands	NSW	Rock shelter	12,550 ± 185	V-35	Charcoal	N. B. Tindale	4, 5
13	Curraurung	NSW	Rock shelter	6,444 ± 74	V-27	Charcoal	I. McBryde	4, 5
14	Burrill Lake	NSW	Sandstone rock shelter	7,450 ± 180	Gak-482	Charcoal	J. V. S. Megaw	4, 5
15	Rocky Cape, South	T	Shell midden in quartzite cave	20,760 ± 80	ANU-137	Charcoal	R. Lampert	6, 7
16	Carlton	T	Open shell midden	8,120 ± 165	Gx0-266	Charcoal	G. Reber R. Jones	4
17	Cloggs Cave, Buchan	V	Limestone cave	8,700 ± 200	I-323	Charcoal	G. Reber	4
18	Keilor	V	River terrace deposits	17,720 ± 840	ANU-840	Charcoal	J. Flood	Personal communication
18	Keilor	V	River terrace deposits	> 18,000 ± 500	NZ-207	Charcoal	E. Gill	6, 8
19	Kow Swamp	V	Lakeside lunette dune	> 31,600 ± 1,100 - 1,300	ANU-65	Charcoal	A. Gallus	4, 5, 6, 8
20	Lake Mungo 2	NSW	Lakeside lunette dune	10,070 ± 250	ANU-403b	Bone 'apatite'	A. Thorne	9
20	Lake Mungo 3	NSW	Lakeside lunette oven	32,750 ± 1250	ANU-331	Unionid shell	J. Bowler	6, 10
20	Lake Mungo 5	NSW	Lakeside lunette, shell midden	30,780 ± 520	ANU-680	Charcoal	M. Barbetti	6
20	Lake Mungo 1	NSW	Lakeside lunette, human cremation	24,020 ± 1480 27,160 ± 900	ANU-372a ANU-372b	Charcoal Unionid shell	H. Allen	6
21	Lake Tandou	NSW	Lakeside lunette dune; shell midden	25,500 ± 1,000	ANU { 618b 375b	Bone 'collagen' and charcoal	J. Bowler <i>et al</i>	6, 10, 16
22	Lake Victoria	NSW	Lakeside lunette dune; oven/hearth	12,350 ± 170	ANU-703	Charcoal	H. Allen	11
23	Lake Menindee	NSW	Lakeside lunette dune; charcoal and hearth?	18,200 ± 800	Gak-2514	Charcoal	E. Gill	11
24	Lake Yantara	NSW	Lakeside lunette dune; hearth	26,300 ± 1,500 18,800 ± 800	LJ-204 Gak-335	Charcoal Charcoal	R. Tedford N. B. Tindale	4, 5, 6
25	Seton Site Kangaroo Island	SA	Limestone aeolianite rock shelter	26,200 ± 1,100	Gak-2121	Charcoal	G. H. Dury T. Langford-Smith	6
26	Koonalda Cave	SA	Limestone sink hole	> 10,940 ± 160 (top of deposit)	ANU-925	Charcoal	R. Lampert	12
27	Puntutjarpa	WA	Rock shelter	21,900 ± 540 19,400 ± 450 23,700 ± 850	ANU-245 { ANU-148 ANU-244	Charcoal Charcoal Charcoal	R. V. S. Wright and A. Gallus	4, 5, 6, 8, 13
28	Devil's Lair	WA	Limestone Cave	10,170 ± 230 24,600 ± 800	SUA-31	Charcoal	R. Gould C. Dortch and D. Merrilees	15 14

Abbreviations of states: TPNG, Territory of Papua and New Guinea; NT, Northern Territory; Q, Queensland; NSW, New South Wales; T, Tasmania; V, Victoria; SA, South Australia; WA, Western Australia.

which is not yet forthcoming. Either there were two populations—an ancient archaic one being added to or partially replaced by a modern one, which entered the continent some time before 25,000 yr ago—or the founding population itself showed marked polymorphism, perhaps due to hybridisation in the region of embarkation¹⁸. The first solution, which seems the most likely at present, also implies that a great slab of Australia's prehistory still awaits discovery.

Technology

Where they are large enough to be diagnostic, the stone tool assemblages from Pleistocene levels of the sites in Table 1 belong to a single pan-continental technological tradition for which the name 'Australian core-tool and scraper tradition' has been suggested¹⁶. These industries are characterised both by their style of retouch and by the tool types themselves. Most implements are scrapers made from cores or thick flakes and, characteristically, they have steep, step-flaked edges with maximum edge angles approaching ninety degrees. Tools include large domed 'horse-hoof' core-scrapers (Fig. 2 *c*, *d* and *e*), a variety of steep-edge scrapers (Fig. 2 *f* and *g*) and notched scrapers (Fig. 2 *h*). The robust tough edges of these tools, together with microscopic evidence of use wear and ethnographic analogies, suggests strongly that they were used as hand-held scraper planes for working wood, the notched and concave ones being spokeshaves for de-barking and smoothing shafts. A second group consists of convex-edged scraper-knives and small round-edged scrapers including 'thumbnail' types (Fig. 2 *i*) with delicate fluted retouch and sharp edge angles. In some sites, bipolar cores provided small sharp flakes for cutting (refs. 14, 19, and personal communication from J. Kamminga).

These were tools to make tools; the main extractive ones²¹, according to the ethnographic evidence, were almost certainly wooden spears and digging sticks, together with a variety of basket work and nets, for which no direct evidence has yet survived from a Pleistocene context.

In spite of the paucity of detailed studies, some broad stylistic provinces are apparent within this tradition, implying the maintenance of populations living in regional groups and transmitting their own cultural idiosyncrasies over periods which can be measured in terms of thousands or even tens of thousands of years^{7,11,17,24}.

In two sites on the edge of the Arnhem Land Plateau (Table 1; 5 and 6), White excavated several edge-ground and grooved axe heads of diorite (Fig. 2 *a*), from levels dating to just over 20,000 BP making them the oldest of their class in the world^{23,24}. These were found with, for example, typical steep-edged scrapers and similar associations have come from levels 10,000 yr old at Ngarradj Warde Djokkeng in Arnhem Land, the Laura rockshelter in Cape York, and Kaviavana in the New Guinea highlands (refs 3, 22, 23 and personal communication from J. Kamminga), showing that right across tropical Greater Australia at least, ground and hafted axes were an integral part of the Pleistocene tool kit. In the New Guinea highlands, functionally analogous tools are the distinctive waisted blades (Fig. 2 *b*), which make their first appearance together with flaked axe adzes in the 26,000 yr old site of Kosipe, and are persistent elements in later assemblages in the same region down to recent times^{2,3,23}. Another type of hafted tool—the mounted flaked adze used until modern times in central Australia—may also have a Pleistocene antiquity. A continuous sequence of these types goes back to 10,000 BP at Puntutjarpa in the western desert¹⁷, and further corroboration now comes from Devil's Lair in the far south west, with examples dating to 12,000 BP. Flakes with marks of gum on them, presumably for hafting or holding, have also been dated back to 14,000 and 25,000 BP at this site¹⁴.

In most of the old sites so far excavated, only the lithic component of the technology has survived, but slowly other aspects are being discovered. Bone tools consisting of stout, ground and polished points usually made from macropod fibulae have been found at several sites including Devil's Lair¹⁴ where they go back to 20,000 yr, Clogg's Cave in south-east Victoria at 12,000 yr (personal communication from J. Flood), Kaviavana, New Guinea²⁵ at 10,000 yr and in four Tasmanian sites, where dozens of points and spatulae have been excavated

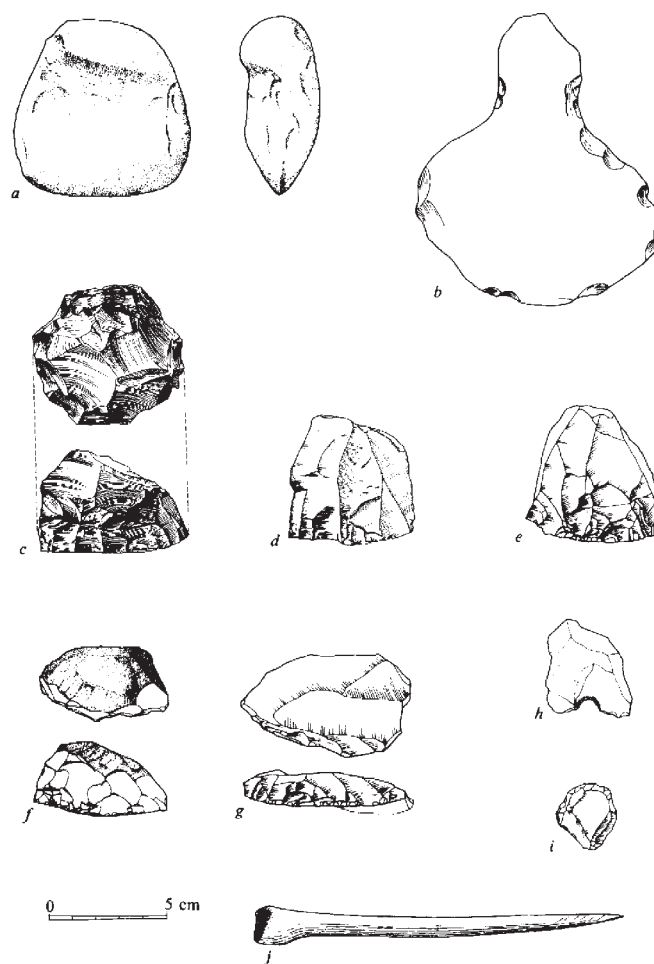


Fig. 2 Some implements of the 'Australian core-tool and scraper tradition'. *a*, Malangangerr, NT (C. White); *b*, Kosipe, TPNG (J. P. White); *c*, Niobe (Nombe), TPNG (J. P. White); *d*, Kenniff Cave, Q (D. J. Mulvaney); *e*, Lake Mungo, NSW (H. Allen and R. Jones); *f*, Rocky Cape, S; T (R. Jones); *g*, Lake Mungo, NSW (H. Allen and R. Jones); *h*, Rocky Cape, S; T (R. Jones); *i*, Burrill Cave, NSW (R. Lampert); and *j*, Devil's Lair, WA (C. Dortch and D. Merrilees).

from levels dated variously from 8,000 up to about 4,000 BP, when they totally disappear from the technology^{4,24}. Their highly distinctive polished use wear, together with ethnographic observations on identical tools, suggests a function as awls and reamers in the manufacture of skin cloaks, such as were used in modern times in south-eastern Australia⁵.

The Australian core-tool and scraper tradition persisted from the earliest sites at 30,000 BP, down to Mid Recent times about 5 or 6,000 BP, when a series of new influences, probably derived from outside Australia became apparent. New Guinea prehistory diverged sharply from that of its mother continent with the introduction of a horticultural economy^{3,23,25}, but the stone tools there still showed remarkable persistence²⁵. In Australia, a range of small tools, such as backed microliths and points were added onto the old technology^{5,17}, and the dingo also entered the continent at this time. Tasmania, isolated for

12,000 yr by the postglacial rising sea, is a special case, since the new influences never reached it. Here a tiny universe of 4,000 hunters survived as direct inheritors of the culture of late Pleistocene Australia until they were destroyed in one generation by civilised man early last century.

Economic Adaptations

Fig. 1 shows that by at least 20,000 BP man was occupying almost all of the principal ecological zones of Greater Australia. During the period under review, the last ice age waxed and waned and caused environmental changes in the highland zones, the continental shelves and the lakes and streams on the edge of the arid zone^{4,10,16}. Yet no matter how much this affected local regions, the basic shape of Australian geography must have been similar to the present day with a large desert core, with its great swirl of continental dunes (Fig. 1), a tropical monsoonal environment to the north, and a cool temperature zone to the south. The arrival of man with fires and hunting pressure had an immense ecological impact, and there is accumulating evidence that man was partially or decisively responsible for the rapid extinction of a large number of 'giant' marsupial and other animals, the principal episode occurring a geologically short time before 30,000 BP. The initial colonisation would have been a period of imbalance and experiment, but by at least 25,000 BP, the distinctive Australian economic system was already in train in some places.

At Mungo, people camped along the sandy beaches bordering the lakes, fishing for golden perch and Murray cod, and gathering freshwater mussels, the shells of which they discarded on midden heaps. From the back scrubs, they collected emu eggs and hunted a wide range of small marsupials including bandicoots and rat kangaroos and cooked their food in earth ovens made by pre-heating lumps of clay^{6,11,16}. In the dry Mungo region, concave sandstone grinding dishes, used for grinding grass seeds into flour, go back from ethnographic times to 15,000 BP; and basal millstones have been found at 18,000 BP in the tropics of Arnhem Land and at 12,000 BP in the rugged hills of south-east Queensland (refs 5, 22 and personal communication from J. Kamminga) implying that a wide variety of seeds and other vegetable foods were part of the diet of late Pleistocene Australians. At the very point in time that the sea reached its present coastline 8,000 BP, the inhabitants of north Tasmania were hunting seals, fishing and diving for shell fish^{4,24}.

There is no reason to think that this coastal economy was a sudden invention conveniently timed to coincide with the end of the Pleistocene, rather the older evidence has been drowned by the rising waters of the Flandrian transgression. This picture of a broadly based foraging pattern extending back from ethnographic times to at least 20,000 BP, has many implications for the study of economic processes in advanced hunting societies. There were no great 'post Pleistocene adaptations'; they had been made a long time before.

The Soul and the Intellect

The young woman at Lake Mungo was cremated and then the calcined bones were smashed and gathered together into a small pit^{10,16,18}. Identical procedures were recorded in Tasmania and the south-east coast of Australia during the last century²⁶, and a continuity for the practice is implied not only by this distribution on both sides of Bass Strait, but also by archaeological finds of cremation pits in Tasmania at 2,000 and the mainland at 10,000 and 12,000 BP^{9,26,27}. A second

Pleistocene burial custom was inhumation, the corpse sometimes being accompanied by grave goods such as stone tools, ochre, shells and animal teeth^{9,27}. The large Lake Nitchie man, buried about 7,000 BP had with him a magnificent necklace consisting of 178 pierced teeth of Tasmanian devils (*Sarcophilus harrisii*), now extinct on the mainland²⁰. Compound burial procedures such as are nowadays practised in northern Australia and perhaps associated with other cultural influences just noted²⁷, seem to have been introduced to the continent in Mid Recent times.

Man left marks of his artistic expression probably as far back as 20,000 BP in the dark subterranean passages of Koonalda^{13,28}, and it is probable that the tradition of rock engravings featuring geometric designs and animal tracks also has a great antiquity²⁸.

When the Upper Palaeolithic sites of Western Europe were first discovered one hundred years ago, it was to the Australian Aborigines that scholars looked for guidance in interpreting their finds. Now, the prehistory of these same Aborigines may mean that decisive innovations in man's cultural development were made on a far broader geographical front than had ever previously been conceived^{8,29,30}.

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Prospects of Astronomy in Australia

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In the first account Dr Bolton, of the CSIRO Division of Radiophysics, Sydney, deals chiefly with radio and solar work. In the second Dr Cannon, formerly a research fellow at Mount Stromlo and now with the United Kingdom 48-inch Schmidt Telescope Unit, highlights the situation in optical astronomy and explains why astronomical research in the Southern Hemisphere is so important.

FOR perhaps ten years after the Second World War, Australia and the United Kingdom shared most of the basic discoveries in radio astronomy. These discoveries have extended the distance horizon of the Universe by an order of magnitude and revealed previously unsuspected sources of energy generation in celestial objects which parallel that of the nuclear energy generated in stars. In many cases, however, the concluding stages of investigations depended on optical astronomers in the United States. It is perhaps fitting that the two countries which independently pioneered the radio field should be partners in a powerful optical instrument, the Anglo-Australian 150-inch telescope at Siding Spring Mountain, New South Wales, for exploration of the relatively unknown southern skies.

Both in Australia and in the United Kingdom the early effort in radio astronomy was made by groups of scientists who had participated in wartime radar development. In Australia the work was concentrated in the Division of Radiophysics of the CSIRO under the leadership of E. G. Bowen and the late J. L. Pawsey. Following Pawsey's initial detection of radio emission from active sunspots, four groups led by J. P. Wild, W. N. Christiansen, B. Y. Mills and myself influenced the direction taken by research at the time; and this in turn led to the present major facilities. Wild, with his dynamic spectrographs, was able to classify and interpret the active phenomena in the Sun's corona—investigations which culminated in the building of Culgoora Observatory. Christiansen with his early grating interferometers, using Earth-rotation synthesis, provided the first high resolution pictures of the Sun at decimetre wavelengths and demonstrated the equatorial limb-brightening. Further developments of this type of instrument led to the Fleurs synthesis telescope, intended for high resolution studies of galactic and extragalactic sources. Mills's investigations showed that radio sources could be divided into two classes, galactic and extragalactic. He was the first to link two aerials by radio in the study of the angular sizes of radio sources and was the inventor of the Mills Cross aerial. The Molonglo Cross is now the most powerful instrument in the Southern Hemisphere for radio source surveys. My own group discovered and identified the sources coincident with the Crab nebula and two external galaxies, M87 and NGC5128. The importance of work on radio sources and later the 21 cm hydrogen line led to the building of the Parkes telescope. Both the new optical facilities at Siding Spring (see accompanying account) will greatly assist the extragalactic research at Parkes and Molonglo.

Mainly Solar

In a short article it is impossible to give more than the briefest description of Australian astronomical facilities and their re-

search work. I shall deal chiefly, but not exclusively, with radio and solar astronomy. Most of the major installations are in New South Wales and all but one of these lie on the 'astronomical meridian' 100–200 miles inland from the coast and the dividing range. It is these facilities that most astronomical tourists to Australia visit.

At the northern end of the 'meridian' is Narrabri Observatory, which is operated by the Chatterton Astronomy Department of Sydney University. This is the site of Hanbury Brown's Stellar Intensity Interferometer with its two mosaic mirrors which can be moved on flat cars on a circular rail track 600 foot in diameter. Observations on early-type stars brighter than 2.5 mag for which the instrument was built were essentially completed a year ago. Angular diameters have been measured for thirty-two stars in the spectral range O5 to F8. Other investigations have been made of close binary stars—for example, all orbital elements and the distance of Spica have been determined. The large reflectors are presently being used to measure the Čerenkov light pulses from the night sky in an attempt to detect high energy γ rays ($\sim 5 \times 10^{11}$ eV) from extraterrestrial sources. It is eventually hoped to replace the present instrument with another, a hundred times more sensitive, for work on fainter stars, particularly the Cepheid variables. A proposal for funding such an instrument has been submitted to the Australian government.

At Culgoora, 15 miles west of Narrabri, the CSIRO Division of Radiophysics operates the world's most advanced solar radio observatory; complementary optical facilities are operated by the CSIRO Division of Physics. There is a small flare patrol telescope and two larger optical instruments. One is a 30-cm refractor designed for photography at high resolution (<1 arc s) in either white light or H α . The other is the 'cinemagnetograph', which provides maps of the solar magnetic field with a spatial resolution of 3 arc s. One of the interesting recent discoveries is of Alfvén waves which flow outwards through the umbra and penumbra of a sunspot.

The radio instruments at Culgoora are the dynamic spectrograph and the radioheliograph. The former records the dynamic spectrum of solar disturbances over the frequency range 8 to 8,000 MHz and provides the basic classification of such disturbances. The radioheliograph provides high resolution pictures of the Sun in both left-hand and right-hand circular polarisation at intervals of 1 s at any one of three frequencies. The heliograph consists of ninety-six parabolic reflectors round the circumference of a circle 3 km in diameter. Signals from the individual aerials are combined to provide forty-eight pencil beams in a north-south line which is step-scanned east-west through sixty positions. At 80 MHz, the initial frequency of the installation, the resulting field of $2^\circ \times 1.6^\circ$ is covered by a matrix of points with a separation of 2.1 arc min; the scanning

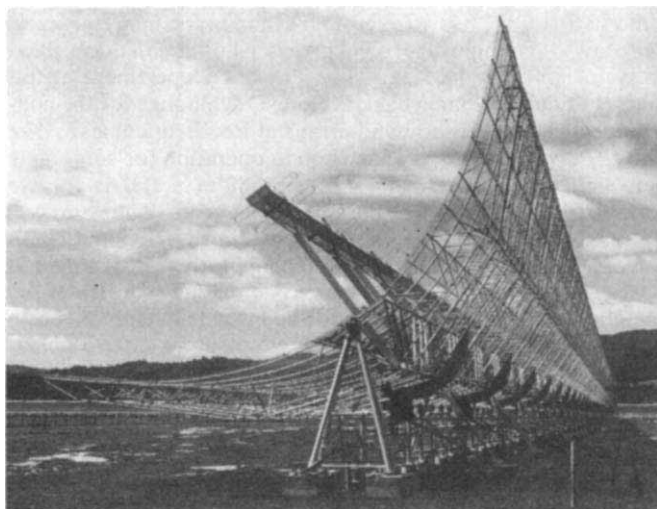


Fig. 1 The east-west arm of the Molonglo radio telescope—operated by the University of Sydney. Overall length is 1 mile. The north-south arm can be seen faintly in the background.

beams have a half-power beamwidth of 3.8 arc min. The same array used at 160 MHz give half the field size and twice the resolution. A second set of forty-eight aerials has recently been added to provide lower resolution pictures at a frequency of 43.25 MHz.

Observations with the heliograph have shown the sources of solar bursts to be complex, frequently multiple, and at times causally connected in widely separated regions. The connection between the regions can be electron streams (leading to delays of seconds) or magnetohydrodynamic shock waves (resulting in delays of minutes). Many types of burst appear to be emitted at or near the plasma level; their source positions give information not only on coronal electron densities, but also on density fluctuations which scatter the radiation and so allow its wide-angled escape from the plasma level.

Although most burst sources remain stationary some have been observed to move away from the Sun for several million kilometres beyond the plasma level. The radio emission in these cases must be synchrotron radiation. Occasionally the radio spectra of high energy flare events contain trains of remarkably regular pulsations which the spectral evidence suggests are modulated synchrotron radiation. Radioheliograph observations of two of these events showed that the apparent angular size of the pulsating source required transverse speeds $\sim \frac{1}{2}c$ to explain the observed simultaneity. Since the pulsations seem to be closely linked with high energy proton events a fuller understanding of their origin might provide clues to the acceleration of cosmic rays.

The large collecting area (6,000 m²) and high resolving power of the radioheliograph make it also a powerful instrument for galactic and extragalactic research. Flux densities, positions and angular sizes at 80 MHz have been measured for over 2,500 radio sources. Some work has been done on pulsars and on the interplanetary scintillation of radio sources.

Seventy miles south of Narrabri is Siding Spring Mountain near Coonabarabran. Chosen as a site to replace Mount Stromlo as the Australian National University's major observing station, it is also the site of the SRC 48-inch and the AAT 150-inch telescopes. Australian National University instruments on the mountain are the 40-inch, 24-inch and 18-inch telescopes.

Mainly Radio

One hundred and fifty miles further south, near Parkes, is the main centre for galactic and extragalactic research of the CSIRO Division of Radiophysics. The principal instrument is the 210-foot reflector. This was the brain child of E. G. Bowen, and its research record has certainly repaid him for perseverance in acquiring the instrument—perseverance

which surely equalled that of Hale. The 210-foot telescope is probably one of the most successful research instruments ever built and there has been steady upgrading of its surface and receiving equipment. The telescope is used by Radiophysics staff and researchers from Australian universities and overseas institutions to carry out a wide range of research in the wavelength range of 1.25 cm to 2 m. A 60-foot telescope, movable along east-west or north-south rail tracks, can be used alone or as an interferometer with the 210-foot telescope at 21 cm.

The well known Parkes catalogue of radio sources at 408 MHz is being replaced by a much more extensive catalogue at 2,700 MHz and identification work is being carried out in cooperation with Mount Stromlo Observatory. With its facility for simultaneous observation at many different wavelengths the telescope has been used extensively for precise determination of pulsar parameters such as their periods, dispersion measures and polarisation. Most of the pulsars studied were discovered at other observatories, but recently eight new pulsars with very high dispersion measures have been discovered at Parkes using an elaborate anti-dispersion technique developed jointly with the Physics Department of the University of Tasmania.

In the past few years the greatest use of the telescope has been in galactic astronomy, particularly interstellar atomic and molecular spectroscopy. The former includes work on the structure of the interstellar medium through 21 cm line absorption studies, the classification of distant sources as emission nebulae or supernova remnants through observation of recombination lines, and the determination of hydrogen-to-helium ratios in emission nebulae in the Galaxy and the Magellanic Clouds. In the molecular field many sources of OH maser emission have been discovered in the southern Milky Way. A number of new molecules have been discovered as have new transitions of molecules already known in interstellar space. The searches for new molecules and transitions are carried out in cooperation with the Chemistry Department at Monash University, which maintains facilities for laboratory measurements of molecular radiofrequency spectra. Unfortunately the Parkes telescope is not capable of efficient operation below 3 cm where the molecular lines are more numerous; the Radiophysics Division intends to build a 25-m telescope to cover the range from 3 cm to 2 mm when funds become available.

At the southern end of the astronomical meridian are the Molonglo Observatory of Sydney University and the Mount Stromlo Observatory of the Australian National University. An image tube camera at the Cassegrain focus of the Mount Stromlo 74-inch reflector has been used to identify over a hundred southern quasars suggested from radio observations at Parkes and redshifts of many southern radio galaxies have been determined with the image tube spectrograph. Two-colour image tube photography using narrow-band filters has been used at the Siding Spring 40-inch telescope to confirm optically as supernova remnants radio sources in the Magellanic Clouds investigated with the Molonglo Cross. Mount Stromlo observers using the Parkes 60-foot telescope have recently found that the 21 cm 'high-velocity clouds'—long a mystery—probably belong to a stream of gas torn from the Magellanic Clouds in their close passage to our own galaxy. Future studies may provide a fairly precise reconstruction of the dynamics of this encounter.

Probably the most interesting recent work has been on X-ray sources. One of these is 2U0900-40 $\equiv$ HD77581, identified at Mount Stromlo. This is a binary and the mass deduced for the unseen companion exceeds the theoretical limit for a neutron star and suggests a 'black hole'. Two other X-ray sources investigated are also candidates for 'black holes'. Supporting evidence is provided by the fact that the X-radiation, presumed to originate from infalling material from the primary, is not pulsed as is the case in other objects where the mass of the secondary is within the neutron star limits.

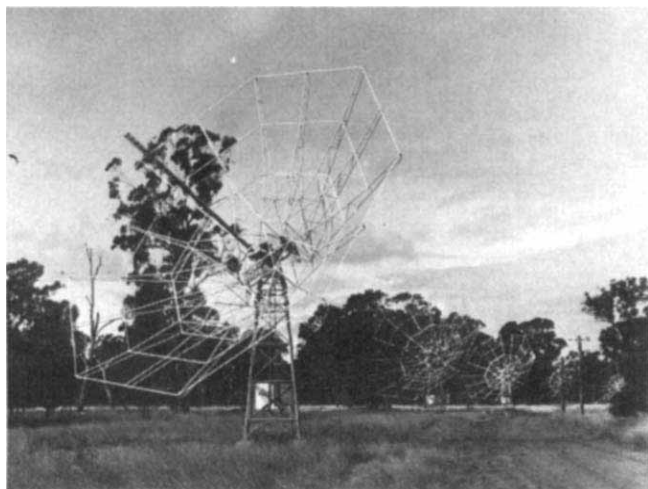


Fig. 2 Some of the ninety-six telescopes that form the Culgoora radioheliograph of the CSIRO.

At Molonglo Observatory there is a Mills Cross with arms 1 mile long operating at 408 MHz with a resolution of 2.8 arc min. A comb of eleven beams along the meridian is produced by simultaneously correlating eleven north-south fan beams with the east-west fan beam. On-line contour maps can be produced on a facsimile recorder. The instrument was designed for a deep survey of the Southern Hemisphere ($\sim 7,000$ sources per steradian). The standard positional accuracy is 10 to 15 arc s, but in special measurements this can be reduced to 2-3 arc s. In addition to the source survey, work at Molonglo includes the identification of supernova remnants in the Magellanic Clouds (discussed previously), spectra and structure of galactic sources—in conjunction with Parkes—and identification of southern quasars and radio galaxies. To aid in the latter a two-coordinate measuring machine has been built. It has been shown that an accuracy of better than 1 arc s can be obtained using the Palomar Sky Survey prints.

The Molonglo telescope, with its very great sensitivity, played an important role in the initial discovery of southern pulsars. At one time over half the known pulsars had been discovered at Molonglo. The results first showed clearly the galactic distribution and the first association of a pulsar with a supernova remnant was suggested.

After completion of the 408 MHz survey, work at Molonglo will probably be phased out and further observations will be made at higher resolution at Fleurs near Sydney. Here the Sydney University School of Electrical Engineering has a rotational synthesis telescope operating at 21 cm wavelength. This is an extension of an instrument built to produce high-resolution pictures of the Sun. A complete map of a region 2° in diameter with a resolution of 40 arc s and a sensitivity of 70 m.f.u. can be obtained in 8 to 12 h. The large number of individual elements provide a complete map in a much shorter time than other synthesis telescopes which use movable elements. With both a north-south and an east-west arm, mapping is possible much closer to the celestial equator than with other instruments. The success of the instrument has been demonstrated by observations of well known objects and routine observations will begin shortly. Projected improvements to the present system are the addition of further elements to double the resolving power and the installation of new r.f. amplifiers to improve the sensitivity five-fold.

Tasmania and Adelaide

Away from the mainland, the island of Tasmania provides an ideal site for low frequency radio astronomy because of both the isolation from terrestrial interference and ionospheric conditions. Grote Reber, one of the American pioneers of

radio astronomy, has worked in Tasmania for many years at very low frequencies. He is currently building a 1-km filled array for work at 1 MHz. The Physics Department at the University of Tasmania has developed techniques for the construction of large broad-band arrays at low frequencies. One array, 760 m in diameter, has been in operation for some time between 2 and 20 MHz and a second, $80 \text{ m} \times 160 \text{ m}$, for use from 40 to 170 MHz will be complete next year. The latter will be used for pulsar searches and will use the same anti-dispersion technique used in the collaborative programme at Parkes. The low frequency array is in use for studies of the galactic continuum radiation and the interstellar free electron distribution through its absorption effects. Extensive observations of the Jovian decametric radiation are also in progress using a novel video recording system to obtain dynamic spectra of the Jovian bursts with a time resolution of $100 \mu\text{s}$ and a frequency resolution of 10 kHz.

Some optical observations are being made with a 40 cm telescope but the main effort is directed towards the completion this year of a 100 cm reflector intended for photometric and photoelectric work. The cosmic-ray group at Hobart is continuing a fifteen-year study of cosmic rays from an underground observatory. A 0.1% variation in intensity with sidereal time has been found. An absorption effect has also been found, apparently due to Jupiter, which, to cosmic rays of rigidity in excess of 100 GeV, appears as a solid disk 1.5 to 2° in diameter.

X-ray astronomy, particularly the study of variable sources, is carried out jointly by the University of Tasmania and the University of Adelaide on rockets flown from the Woomera range. The Physics Department at the University of Adelaide also carried out ultraviolet rocket-borne experiments. The absolute solar flux has been determined in the range of 1,400 to 1,700 Å and the minimum solar temperature measured at $4,570 \pm 50 \text{ K}$. The lunar albedo has been found to drop sharply in the ultraviolet to 0.7% at 2,400 Å and 0.3% at 1,216 Å.

Radar investigations of meteors, begun in Adelaide in 1950, are continuing, with the principal interest in atmospheric investigations. Studies of the solar wind through interplanetary scintillation of compact radio sources are being made at 112 and 236 MHz with aeriels at Buckland Park near Adelaide and sites 150 miles north-east and north-west. The aerial at Buckland Park consists of four 200 m corner reflectors with two such reflectors at the outstations. Also at Buckland Park is an array of 178 dipoles on a circle 1 km in diameter. This is at present used for ionospheric sounding at 2 MHz and 6 MHz but it will be used in conjunction with an ultrasonic image-forming system for low frequency radio astronomy near the next sunspot minimum. Finally the radio pulses from cosmic-ray air showers have been found to have an unexpectedly high signal-to-noise ratio near 100 kHz leading to the possibility of the construction of an extensive array of 100 kHz detectors for the discovery of ultrahigh energy ($>10^{19} \text{ eV}$) cosmic-ray primaries.

Important Role

So much for the major facilities. This account would not be complete, however, without a reference to the State Government Observatory at Sydney, founded in 1856. This observatory and the one at Perth are the two oldest in Australia. Sydney Observatory played an important though little recognised part in the early stages of radio astronomy in Sydney. It provided the first contact for the radiophysicists with the then conventional astronomy. Its director, Harley Wood, and C. W. Allen at Mount Stromlo Observatory were two people who, for the time, showed a surprising faith in our observations of 'cosmic noise' and 'solar noise' and were always available for consultation. To end on a personal and somewhat nostalgic note, it is twenty-five years ago, this month, that I telephoned Harley Wood and said, "I think that I have identified one of my radio sources. What can you tell me about the Crab nebula?" What, indeed!

R. D. CANNON

UK 48-inch Schmidt Telescope Unit, Blackford Hill, Edinburgh EH9 3HJ

AUSTRALASIAN astronomy is of course predominantly Australian astronomy, which today occupies a leading position in the world. This is partly due to a fortunate combination of circumstances: geographical location, giving access to the southern skies which happen to be more important than the northern skies in many fields of research, a good climate, good sites relatively free from man-made interference and an advanced technology. Astronomy is not, however, a young subject in Australia. Over a century ago the Great Melbourne Telescope, with a 48-inch speculum mirror, was one of the world's largest. Initially rather unsuccessful, a much modified version of this telescope containing at least some of the original components is still in regular use on Mount Stromlo. By the turn of this century there were three major government observatories in Australia, at Sydney, Melbourne and Perth, and all three participated for several decades in the international programme to produce the *Astrophysical Catalogue* and *Charts* covering the entire sky, using standard 13-inch refractor telescopes.

Sydney and Perth Observatories are both active today, mainly in various aspects of positional astronomy, but Melbourne Observatory was closed in 1944 and much of its equipment and library were moved to the then Commonwealth Observatory at Mount Stromlo near Canberra. The latter grew to become Australia's major optical observatory, and is now part of the Research School of Physical Sciences at the Australian National University (ANU). Its pre-eminence in optical astronomy is now passing to Siding Spring, a mountain in the Warrumbungles near Coonabarabran, some 400 miles north of Canberra. Siding Spring Observatory started almost 10 years ago as a field station of Mount Stromlo when the city lights of a rapidly expanding Canberra began to interfere seriously with astronomy. It is now also the site of the United Kingdom 48-inch Schmidt Telescope, and of the nearly completed 150-inch Anglo-Australian Telescope (AAT). Although it is not one observatory administratively, it is to be hoped that there will be close collaboration between the different groups of astronomers on Siding Spring Mountain.

In addition to these conventional observatories, there are two highly specialised optical installations in Australia. These are the Narrabri Stellar Intensity Interferometer, used primarily for the measurement of star diameters, and the Culgoora Solar Observatory of the CSIRO (see accompanying account).

Why Southern Astronomy?

There are several very good reasons why astronomy in the Southern Hemisphere is important. In the first instance, in many fields it is desirable to have complete surveys covering the whole sky. In the study of the structure and dynamics of our own Galaxy, the overall distribution and motions of special types of objects such as star clusters, different kinds of variable stars, pulsars, HII regions and neutral hydrogen, are needed. In cosmological studies, it is very important to know whether or not quasars, radio galaxies and clusters of galaxies are uniformly distributed over the sky and whether or not their velocities are isotropically distributed. For most of these purposes the task is simply to extend northern programmes and catalogues to the south, although in many cases the southern data are now better and more uniform than the northern.

The more exciting projects are those involving specifically southern objects, and it happens by chance that, for many purposes, the Southern Hemisphere is the more important. First and foremost is the fact that the centre of our own Galaxy is situated at -29° declination. Thus, although it is accessible from the major observatories in the southern United States, it is always low on the horizon and only observable for short

periods; by contrast it passes almost through the zenith for Australian observers, and can be followed continuously for many hours with the minimum loss due to atmospheric transparency and turbulence. The galactic centre is, of course, interesting *per se*, particularly at infrared and radio wavelengths which penetrate the intervening matter in the Milky Way, but a secondary consequence is that some classes of objects, for example the globular clusters, are mostly in the Southern Hemisphere.

Globular clusters are important in understanding the history and structure of our Galaxy, as test objects for the theory of stellar evolution, and in the study of stellar dynamics. In addition to the large number of clusters near the galactic centre, the Southern Hemisphere also contains the nearest globular cluster, NGC6397, and two of the richest and most interesting nearby globulars, ω Centauri and 47 Tucanae. All of these three are south of declination -45° and inaccessible from northern observatories. Perhaps even more important, Australian telescopes have access to the star clusters in the Magellanic Clouds, clusters which seem to be quite different to any in our own Galaxy.

The Magellanic Clouds provide the third and in many ways the best reason for building telescopes in Australia. These Clouds, which appear superficially like detached parts of the Milky Way and which may indeed be satellites of our Galaxy, are much the nearest external galaxies apart from a few dwarf systems more akin to globular clusters, and they lie mainly between declinations -60° and -75° . The study of these two relatively small galaxies may well lead to a basic understanding of how the stars, gas and dust interact in galaxies and of galaxy dynamics and the formation of spiral arm features; by providing

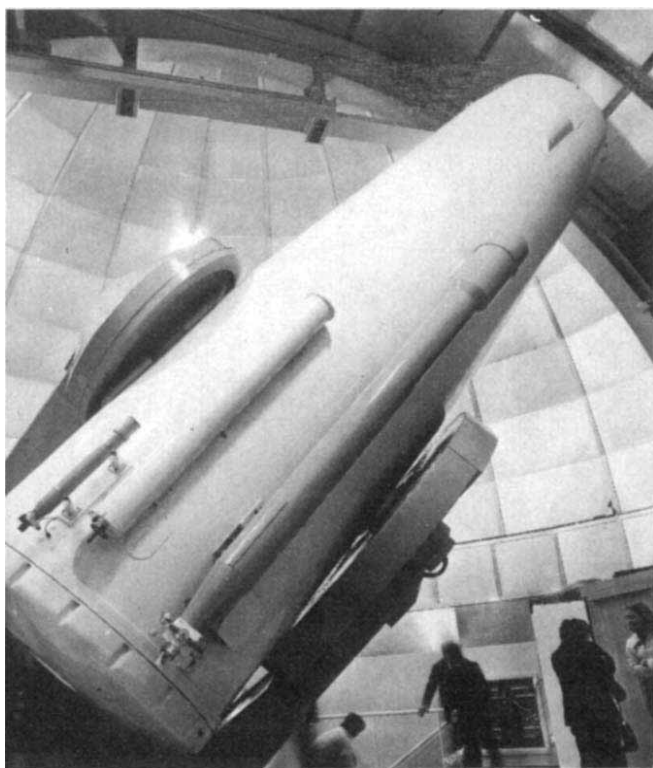


Fig. 1 The United Kingdom 48-inch Schmidt telescope.

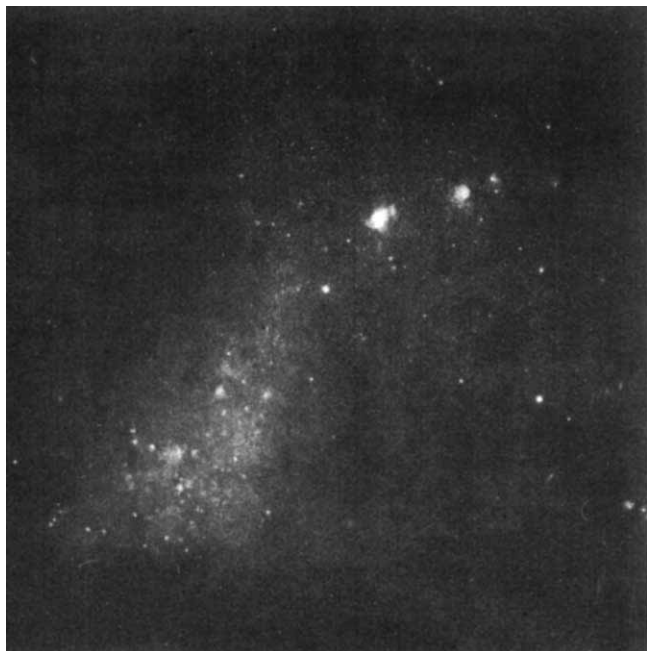


Fig. 2 Reproduction of a photograph taken with the 48-inch Schmidt telescope of the United Kingdom Science Research Council, showing the Small Magellanic Cloud.

large samples of all types of objects at almost the same distance, they can also be used to calibrate various distance indicators, as they were for example early this century in setting up the fundamental Cepheid period-luminosity relation.

Astronomy at the ANU

Having outlined some of the reasons why astronomy is important in Australia, I shall describe the work of some of the Australian observatories. The staff at Mount Stromlo and Siding Spring Observatories includes about two dozen research astronomers, approximately equally divided between permanent and short term appointments. There is thus a steady turnover of staff, and a constantly shifting emphasis in the research; there is no single overriding theme in the topics studied. The Mount Stromlo 74-inch is still, with a sister instrument at Pretoria in South Africa, the largest operational telescope in the Southern Hemisphere, and as such is used for a great range of observations; it has instrumentation at three foci: Newtonian, Cassegrain and Coudé. Present projects include high dispersion spectroscopy of bright stars to look for chemical composition anomalies; low dispersion spectroscopy of galaxies to add to the cosmological data on northern galaxies; observations to identify and measure the redshifts of quasars and radio galaxies; the measurement of internal structure and velocities in the nearer galaxies and star clusters; and faint broad-band photometry of star clusters in the Magellanic Clouds and our own Galaxy. The old 50-inch telescope has been extensively used with a photo-electric scanner to determine stellar continuum energy distributions, and a new thirty-three-channel spectrophotometer is now in use on the 74-inch. Other new equipment will permit work in the infrared out to 20 μm on any of several telescopes, including the recently renovated Reynolds 30-inch reflector. There are three ANU telescopes on Siding Spring Mountain, comprising 40- and 16-inch conventional reflectors and a 24-inch reflector with a rotating tube specially designed for polarisation measurements. All three telescopes are used primarily for broad, intermediate and narrow wave-band photoelectric measurements of large sam-

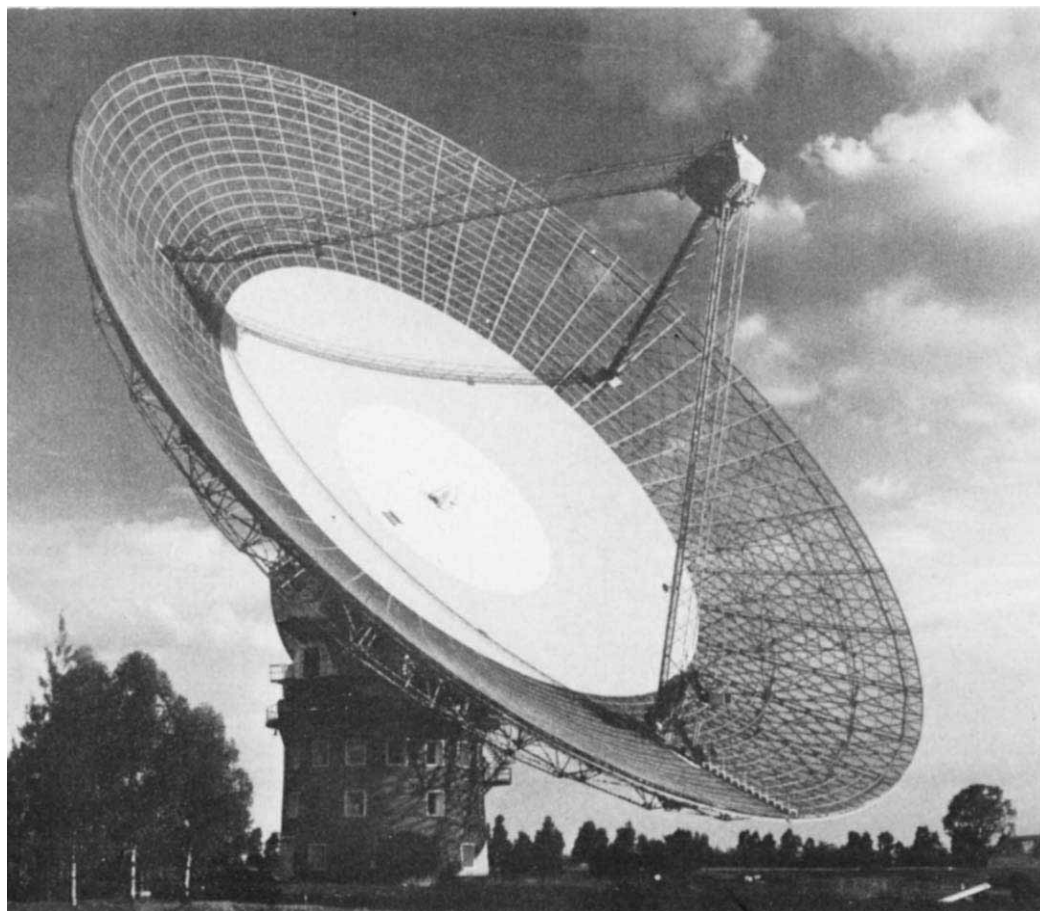


Fig. 3 The 64-m (210-foot) radio telescope at the CSIRO Parkes Observatory, a vital complement to the new optical facilities at Siding Spring.

ples of stars, mainly directed towards elucidating the structure and dynamics of our own Galaxy and some aspects of stellar evolution.

Other Australasian Astronomy

New Zealand has a long tradition of optical astronomy, and is particularly active in the international programmes to monitor bright variable stars. The principal modern observatory is the Mount John Observatory in South Island, operated jointly by the Universities of Canterbury at Christchurch, Pennsylvania and Florida, whose most important work to date is the recently published Canterbury Sky Atlas made using a 24-inch reflector telescope; this should be a useful adjunct to the forthcoming much deeper, larger scale Schmidt surveys. Mention must also be made of the Carter Observatory in Wellington, which fulfils the usual role of a government observatory.

There is another observatory of note in Australasia, the Bosscha Observatory at Lembang in the Indonesian island of Java. The two main instruments here are a 24-inch double refractor and a 20-inch Schmidt telescope, which are used to observe double stars and for photometry of star clusters.

Future Prospects

In the immediate future, the most exciting prospects are in optical astronomy which may be able to recapture some of the glory which has rightly fallen mainly to Australian radio astronomy in recent years, and which has in fact provided much of the motivation for the new optical instruments. The United Kingdom 48-inch Schmidt telescope, owned and operated by the Science Research Council, has recently come into operation on Siding Spring Mountain. It is a specialised instrument, designed only for wide-angle direct photography of the sky, or at a later stage for very low dispersion spectroscopy using an objective prism. It was built primarily to extend the National Geographic Society-Palomar Observatory Sky Survey to the south, and is very similar to the Palomar 48-inch Schmidt; the survey will be done in collaboration with the European Southern Observatory's new 1-m Schmidt at La Silla in Chile.

Important uses of this survey will be the completion of northern catalogues of objects like peculiar galaxies and clusters of galaxies, the identification of radio and X-ray sources, and studies of the distribution of stars and galaxies over the sky. In many fields it will act as an adjunct to the 150-inch AAT, providing source lists of interesting objects for further study.

The 150-inch Anglo-Australian Telescope, with four times the light grasp of the largest telescopes operational at present in the Southern Hemisphere, should make many exciting discoveries; it may well be the first of the new large southern telescopes in regular operation since it is due for completion during 1974. The prime fields of research will probably be the Magellanic Clouds, the centre of our own Galaxy, and interesting peculiar objects such as the radio galaxy Centaurus A (NGC5128). In all these fields, there will have to be close collaboration between optical, radio and the rapidly developing astronomy at other wavelengths.

Recent astronomical research in Australia has opened up so many promising lines of research that the biggest problem at present is to decide on priorities for future instrumentation. For example, three recent major Australian proposals are for a millimetre radio telescope to continue the Parkes/Monash work on interstellar molecules, a new much larger stellar intensity interferometer to extend the Narrabri work to fainter stars, and a 60-inch conventional optical telescope as support for the 150-inch AAT. Although this last is an Australian proposal, there are strong reasons why the UK also should consider providing more supporting telescopes, so that British astronomers can make efficient use of their time while in Australia working on the AAT; the 48-inch Schmidt will only be able to meet part of the need in this respect, and the existing smaller Australian telescopes are already over-subscribed by Mount Stromlo astronomers so that there is unlikely to be much time available on them for visitors. Another obvious gap in existing Australian instrumentation is the lack of a really accurate positional radio telescope. Radio positions are now being determined in the Northern Hemisphere to accuracies of about 1 arc s, but the best southern catalogues give accuracies of only about 6 arc s which is not good enough for unambiguous optical identification of radio sources, particularly of any without obvious optical peculiarities. Furthermore, it seems likely that radio astronomy may in the future provide the basic reference frame for astrometry since it is already capable of higher positional accuracy than traditional optical techniques.

100 Years Ago

THE forthcoming number of Petermann's *Mittheilungen* will contain an interesting article compiled from the Australian papers, giving an account of a three months' journey during August, September, and October of last year into the interior of Australia, by Mr. Ernest Giles, accompanied by Messrs. Carmichael and Robinson. They struck off from the route of the overland telegraph at Chambers's Pillar, about 133° 55' E. long., and 24° 53' S. lat., and journeyed in a north-west direction along Finke Creek, traversing ground which has not hitherto been explored. They passed among long ranges of hills, lying in an east and west direction, and varying in height from a few hundreds to 4,000 ft., though few of the heights are apparently above 1,000 ft. At about the 24th parallel, in 133° N., they came upon multitudes of magnificent fan palms growing along the bed of the creek; they named the place the "Glen of Palms." Their journey in this direction extended to 129° 55' W., and about 23° 10' S., the utter sterility of the region and the want of water compelling them to turn back. It was only during the last few days, however, of their western journey that water became scarce. The most characteristic vegetation throughout was *Spinifex*; *Casuarina* was also of frequent occurrence.

From *Nature*, 8, 94, May 29, 1873.

WELLINGTON N.Z. PHILOSOPHICAL SOCIETY

The President referred to the expected visit of the *Challenger* on a scientific exploration of the Southern Seas, and expressed a hope that it would add largely to our knowledge on this interesting subject. Referring to the great Southern Continent, which is full of interest with its active volcanoes amidst perpetual snows, he stated it was likely that the ensuing year will add greatly to our knowledge of that land, which is only 1,200 miles distant from New Zealand, on whose climate it probably exerts a marked influence. This little known land possesses large supplies of guano, and according to Sir James Ross, has a large and undisturbed whaling ground near it, in which whales of several different species abound. The President criticised Captain Huton's paper on the Glacial period of New Zealand, and confirmed his dissent from the theory of a submergence of the New Zealand area on a grand scale during the post-pliocene or post-glacial period, and stated that unless palaeontological evidence of recent date can be obtained from strata occupying valleys that were eroded during the last extension of the glaciers he must still adhere to his formerly expressed opinion, that the geological period previous to that which may be termed the recent period in New Zealand was characterised by a prolonged though perhaps not excessive elevation; and that especially in the South Island there is in consequence a marked absence of marine drifts and tills. The President commended the study of the subject of our soils, surface drifts, and beach rocks to the members of the Society.

From *Nature*, 9, 173, January 1, 1874.

Relative Motion of Hot Spots in the Mantle

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Reconstruction of the major lithospheric plates 21 and 38 m.y. ago implies that linear island chains and aseismic ridges were not generated by localised sources of volcanism (hot spots) that have been fixed with respect to one another. If the linear volcanic chains are formed over mantle hot spots, the spots move at rates of 0.8 to 2 cm yr⁻¹ with respect to one another.

CAREY¹ suggested that many of the aseismic ridges observed on the ocean floor are manifestations of hot spots in the mantle and assumed, as Dietz and Holden² did later, that these aseismic ridges could be used in reconstructions of continents earlier in the Cainozoic. Wilson^{3,4} further suggested that they were generated as the seafloor moved over localised zones of upwelling that are fixed with respect to one another in the mantle beneath the asthenosphere. Morgan^{5,6} attributed the hot spots to convective plumes rising from the lower mantle. We explore here the assumption that the hot spots are fixed with respect to one another and therefore define a reference frame with respect to which the plates move.

Reconstruction of Plates

One test is to examine the relative positions of the major plates at some time in the past and locate one of them properly over its hot spots. If all the hot spots are fixed with respect to one another, then they should all underlie the linear volcanic chains that they generated. Minster *et al.*⁷ used inversion techniques to obtain a refined version of recent relative plate motions, and made a preliminary test by comparing the trends of linear volcanic chains with those predicted. They found no observable relative motion of the hot spots during the past few million years. Because changes in spreading rates occurred between about 5 and 20 m.y. ago at nearly every major spreading centre in the oceans, their instantaneous velocities are probably not useful for periods earlier than 10 m.y. ago.

The relative positions of pairs of plates at different times earlier in the Cainozoic have been reconstructed in the North Atlantic Ocean⁸, in various parts of the Indian Ocean⁹⁻¹¹, and in the South Pacific¹². Spreading in the

South Atlantic has been relatively constant, so that Le Pichon's¹³ original pole and angular velocity are probably sufficient for our purposes. These studies allow one to interrelate the motions of all the major plates.

We reconstructed the plates to their positions with respect to one another at different times in the Cainozoic. Then, assuming the Hawaiian-Emperor chain to be the expression of the motion of the Pacific Plate over the Hawaiian hot spot, we rotated the Pacific Plate along with the reconstruction of the other plates to their positions with respect to the Hawaiian hot spot. The reasons for constraining the reconstructions to agree with the inferred relative positions of the Pacific over the Hawaiian hot spot are: (1) using other island chains in the Pacific Ocean the pole of relative motion between the Pacific Plate and the hot spots can be well determined; (2) the dating of islands along the chain is more complete than along any other; and (3) there is more complete agreement that the Hawaiian Islands were generated by a hot spot than for most of the other suggested ones. If the other hot spots did not move with respect to the Hawaiian spot, then for each of these reconstructions the linear volcanic chains should overlie the hot spot that generated them.

We considered the hot spots and linear volcanic chains listed in Table 1. These were selected because they are among the more popular ones and they have a balanced geographical distribution. We recognise that there is no unanimity as to what constitutes a well defined hot spot.

We made reconstructions for 21 and 38 m.y. ago. For earlier times, the data are not yet adequate to reconstruct the major plates reliably. For 21 m.y. we used reconstructions to anomaly 6 in the Pacific, South-east Indian and South Atlantic oceans and interpolated between earlier and later reconstructions in the North Atlantic and North-east Indian Ocean. Assuming the age of Midway Island to be 18 m.y.¹⁴, the position of the inferred Hawaiian hot spot with respect to the Hawaiian chain 21 m.y. ago is relatively

Table 1 Hot Spots and Volcanic Chains

Hot spot	Linear volcanic chain	Fig.
Hawaii	Hawaiian Islands	1
Gough Island and Tristan da Cunha	Walvis Ridge and Rio Grande Rise	2
Réunion	Mauritius Plateau and Chagos-Laccadive Ridge	3
Kerguelen	Ninety East Ridge	4
St Paul's and Amsterdam Island	Ninety East Ridge	4
Iceland	Greenland-Iceland and Iceland-Faeroes Ridges	5
Yellowstone	Snake River Basalts	1

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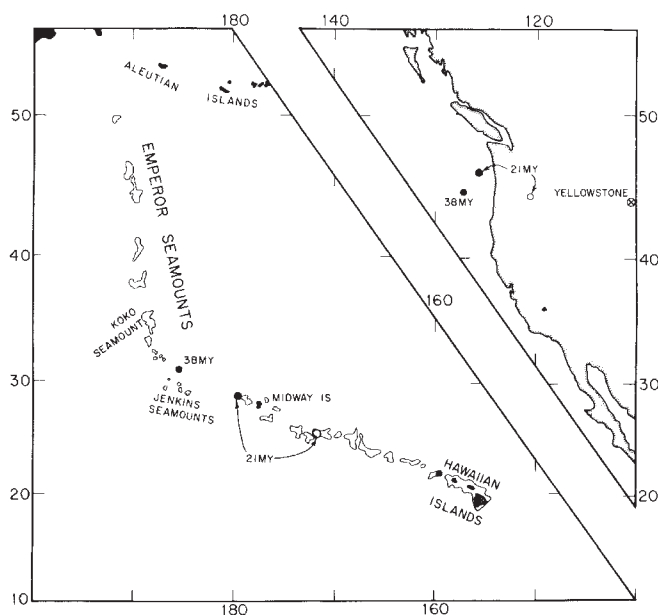


Fig. 1 Left, Hawaiian-Emperor chain and positions of the Hawaiian hot spot at the present and at 21 and 38 m.y. ago. Position at 38 m.y. ago is based on the age of Koko seamount¹⁵. Two estimates for 21 m.y. ago assume: ●, Jackson *et al.*¹⁴ date of Midway or ○, constant rate of Pacific motion over hot spot. ⊗, Present position of hot spot. Right, calculated position of Yellowstone hot spot with respect to North America at 21 and 38 m.y. ago.

well defined (Fig. 1). Assuming that the hot spots are fixed with respect to each other, the reconstructed positions of the plates at 21 m.y. show that, except for the Ninety East Ridge, the other hot spots do not underlie the aseismic ridges generated by them (Figs 2 to 5). If the 18 m.y. age of Midway approximately dates the passage of the Hawaiian hot spot, that spot cannot be fixed with respect to the others⁷.

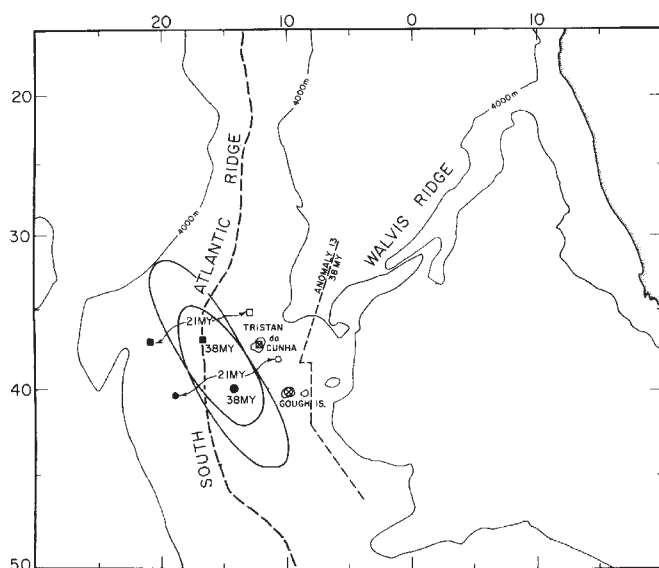


Fig. 2 Relative positions of hot spots under Gough Island and Tristan da Cunha with respect to the African Plate. Symbols as for Fig. 1. Confidence oval surrounds position for 38 m.y. ago. If fixed to the Hawaiian hot spot, the two proposed hot spots should underlie the Walvis Ridge beneath material older than 21 m.y. and 38 m.y. The calculated positions lie beneath material that had not yet been formed at these times. Therefore, at these times, they lay beneath the South American Plate, south of the Rio Grande Rise. They could not have generated these rises and also been fixed to the Hawaiian hot spot.

In view of the possibility that the Midway age does not date the formation of the island, we decided to explore the possibility that the rate of motion has been constant for 42 m.y. during the entire formation of the Hawaiian chain (Fig. 1). Although the disagreement is less than for the case above (open circles in Figs 2 to 5), the calculated positions of the other hot spots still do not lie under the traces presumed to be generated by them. Because of the various interpolations involved in the 21 m.y. reconstruction, this conclusion is, however, not inescapable.

The reconstructions for 38 m.y. ago provide a more definitive test. Dating of Koko seamount¹⁵ constrains the Hawaiian-Emperor bend to be about 42 m.y. old¹⁶. Anomaly 13, a prominent magnetic anomaly used in the reconstructions of most oceans, was formed approximately 38 m.y. ago. Thus the uncertainties both in the relative positions of the major plates and in the assumed position of the Pacific Plate with respect to the Hawaiian hot spot are likely to be smaller than for other times. The relative

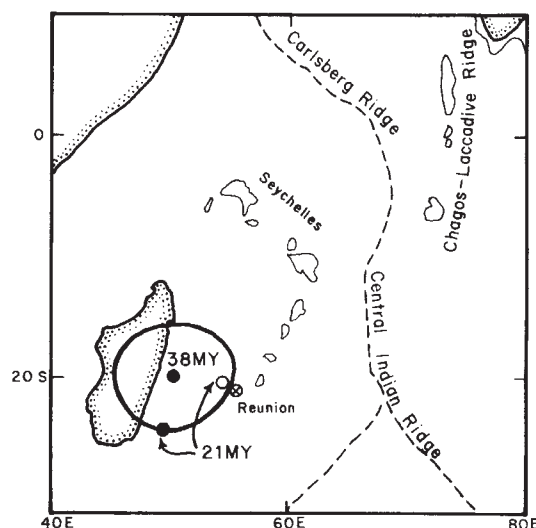


Fig. 3 Relative position of the hot spot under Réunion with respect to the African Plate. Symbols same as Figs 1 and 2. The Mauritius Plateau and the Chagos-Laccadive Ridge were continuous 38 m.y. ago^{9,10}. If this hot spot generated the Mauritius Plateau, and the Chagos-Laccadive Ridge on the Indian Plate, and fixed with respect to the Hawaiian hot spot, it should lie beneath the Mauritius Plateau north-east of Réunion. It does not.

positions of the hot spots and their associated linear island chains at 38 m.y. are shown in Figs 2 to 5. Except for the possibility that a hot spot beneath Kerguelen generated the Ninety East Ridge, the calculated positions of the spots are not coincident with the chains presumed to be generated by them. If the hot spots formed these chains, they have moved 300 to 800 km with respect to the Hawaiian hot spot, that is, at rates of 0.8 to 2 cm yr⁻¹. These rates are comparable with those for relative motions of most of the plates, although they are significantly slower than those in the Pacific.

Uncertainties and Assumptions

The uncertainties in the reconstructions result from two sources: errors in individual reconstructions and validity of the assumptions. Both are difficult to evaluate. One may gain a crude, upper limit for the reconstruction errors in the following manner. The uncertainties in the positions of the poles matter very little except that they are coupled to uncertainties in the angles of rotation. The uncertainties in the angles are not likely to be greater than 1° (perhaps

2° for the Pacific hot spot rotation). Thus at the equator for each rotation, an error of about 100 km could result. For example, the position of Gough Island with respect to Africa requires four rotations (Africa→India→Antarctica→Pacific→Hawaiian hot spot). The maximum uncertainty would be about 400 km. As Gough Island does in fact lie near the equator of each of the four rotations, this estimate is a reasonable upper limit. The motion of the Iceland hot spot with respect to the North American Plate involves five rotations (North America→Africa→India→Antarctica→Pacific→Hawaiian hot spot). In three of these (the first one and the last two), the pole of rotation is near Iceland. Thus the error in relative position should be considerably less than 500 km.

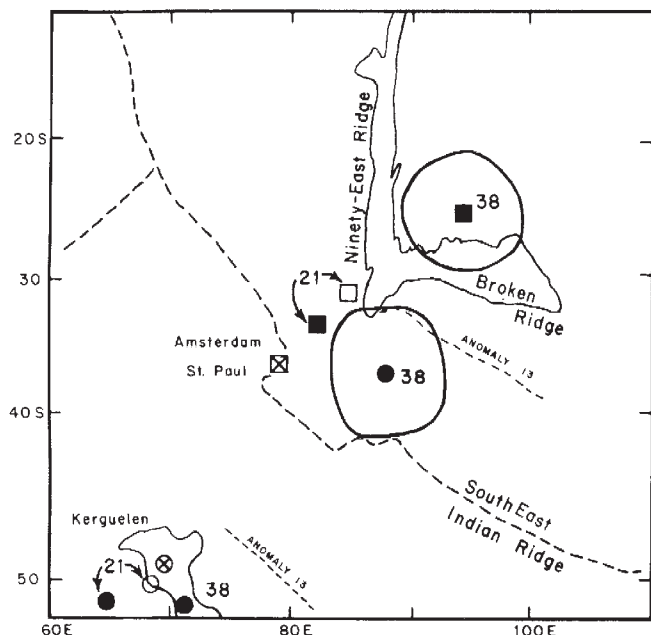


Fig. 4 Relative positions of hot spots beneath St Paul's and Amsterdam Islands with respect to the Ninety East Ridge on the Indian Plate (squares); and of Kerguelen hot spot with respect to the Kerguelen Plateau on the Antarctic Plate (circles) and with respect to the Indian Plate for 38 m.y. ago (closed circle with confidence oval). Symbols as in Figs 1 and 2. If either of these hot spots had generated the Ninety East Ridge and were fixed with respect to the Hawaiian hot spot, it should lie between the Ninety East Ridge and Kerguelen 21 and 38 m.y. ago. If a hot spot exists beneath Kerguelen and generated the Kerguelen Plateau, it should have lain beneath it during the past 38 m.y. The data do not rule out the possibility that a hot spot beneath Kerguelen, fixed with respect to Hawaii, could have generated both of these features. No such feature beneath St Paul's and Amsterdam Islands could have produced the Ninety East Ridge.

Since the above error estimates tend to be excessive, we performed a more realistic calculation. We were not able to treat the uncertainties in a statistically rigorous manner, so we simply estimated the maximum uncertainty in each of the finite rotations and explored the range of possible combinations of them. This procedure allowed determination of ovals describing the largest possible errors in the relative positions of the hot spots with respect to the plates. These ovals are shown in Figs 2 to 5 for the reconstructions for 38 m.y. ago. They show that the relative motion of any given hot spot with respect to the Hawaiian hot spot can be reduced by about a factor of two. Because the uncertainties are not independent, it is not, however, possible to reduce all of the motions this much.

Apart from assuming the Vine-Matthews hypothesis to be correct so that given anomalies on opposite sides of a

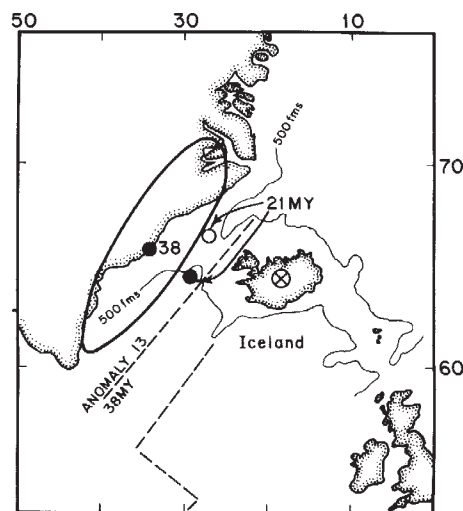


Fig. 5 Relative positions of a hot spot beneath Iceland with respect to the North American Plate. Symbols as in Figs 1 and 2. If the ridges between Greenland and Iceland and between Iceland and Europe were produced by a hot spot beneath Iceland, it would have been centrally located with respect to Greenland and Europe during the past 38 m.y. When fixed with respect to Hawaii, it is found to have underlain the North American Plate during this time, and therefore could not have generated the Iceland-Faeroes Ridge.

spreading centre were formed at the same place, the crucial assumption is that the plates are rigid. There seems to be no reason to doubt this in the oceanic areas. We neglected deformation along the East African Rift, because it is much smaller than the uncertainties discussed above. The possibility of deformation in Antarctica is difficult to eliminate. Motion between East and West Antarctica has occurred since the Jurassic¹⁷⁻¹⁹ and seems to have continued into the Cainozoic¹². The reconstruction of the South-West Pacific Ocean at 38 m.y. does not require younger deformation¹², so we assume that Antarctica has behaved rigidly since then. In any event, if deformation has occurred since 38 m.y. ago in the same sense as earlier, it seems that the resulting relative positions of the hot spots and associated linear chains would differ even more than shown in Figs 2 to 5.

Perhaps the strongest justification for the reconstructions used here comes from the estimated relative position of the Pacific and North American plates, for 38 and 29 m.y. (ref. 20). These reconstructions place the extinct Pacific-Farallon spreading centre a few hundred km west of North America at 38 m.y. ago, and within 200 km of the coast 29 m.y. ago. These calculated positions agree well with those inferred from the magnetic anomalies in the Pacific Plate west of California^{21,22} and their differences are far less than the maximum uncertainties cited above.

We carried out one other check. If there was some unknown deformation within one of the plates or if the reconstruction between one pair of plates was grossly in error, and if the hot spots were fixed, then an additional, arbitrary rotation exists that when added into the sequence of rotations would allow all of the aseismic ridges to overlie their respective hot spots. To carry out such a search rigorously is expensive and tedious. But a manual examination using a globe revealed no such arbitrary rotation. For instance, rotations that caused the Iceland hot spot to lie beneath the Iceland-Faeroes ridge invariably left the Walvis Ridge far north of the hot spot inferred to lie at present beneath Gough Island or Tristan da Cunha.

Implications for Plate Motion

If the hot spots are fixed with respect to each other, what does this imply for plate motions and the origin of linear

volcanic chains? First⁷, it requires that Midway be considerably older than the date given by Jackson *et al.*¹⁴. Second, more than one of the pole positions and finite rotations used here must be grossly in error. Third, there must be a large internal deformation within Antarctica since 38 m.y. ago, in some sense different from that calculated to have occurred earlier in geological time¹². We consider a simpler interpretation to be that the hot spots do not define a fixed reference frame, that the Hawaiian hot spot moves at velocities with respect to the others that are comparable to the velocities of relative plate motions, and that the others also move with respect to one another. Burke *et al.*²³ reached a similar conclusion concerning motions among the various Atlantic hot spots since the Cretaceous, and McElhinny²⁴ concluded that hot spots could not be fixed both with respect to one another and to the spin axis of the Earth. Although relative motion of the hot spots of the magnitude suggested here does not prove that plumes do not exist, it does refute one of the most appealing aspects of the idea: a fixed reference frame with which to describe the motions of the plates; and it removes a strong impetus for placing their origin in the lower mantle.

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Sequence of Events in Plasma Membrane Assembly during the Cell Cycle

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Major components of the plasma membrane double during interphase. Some minor components also double, but others show fluctuations. Decreased expression by immune cytotoxicity of H-2 antigenicity during interphase is explicable in terms of decreased membrane fragility. These results are compatible with a model in which plasma membrane assembly occurs throughout interphase and in which cytokinesis is essentially a physical process.

THE importance of the cell surface in biological processes makes knowledge of the mechanism of its assembly highly

pertinent. At present, for example, it is not known whether the components are synthesised predominantly during mitosis or during interphase. The development¹⁻⁹ of a technique^{10,11} of separating cells by size according to their position in the cell cycle has enabled us to make some initial observations¹² on the assembly of cellular membranes; we found that the protein, as well as some specific enzymes, of nucleus, mitochondria and endoplasmic reticulum doubles during interphase. A procedure for isolating plasma membrane^{13,14} has now enabled us to study the assembly of its components during the cell cycle. An extension of previous observations¹⁵ on the expression of surface antigens provides further support for a model for the assembly of the plasma membrane¹⁶⁻¹⁸.

Ratio of Surface Area to Volume

Like most cultured cells, those used in this study double in volume between G_1 and G_2 (ref. 6). Since they are spherical the surface area increases by a factor of $2^{2/3}$ or approximately 1.6; the extra 0.4 is presumably made up

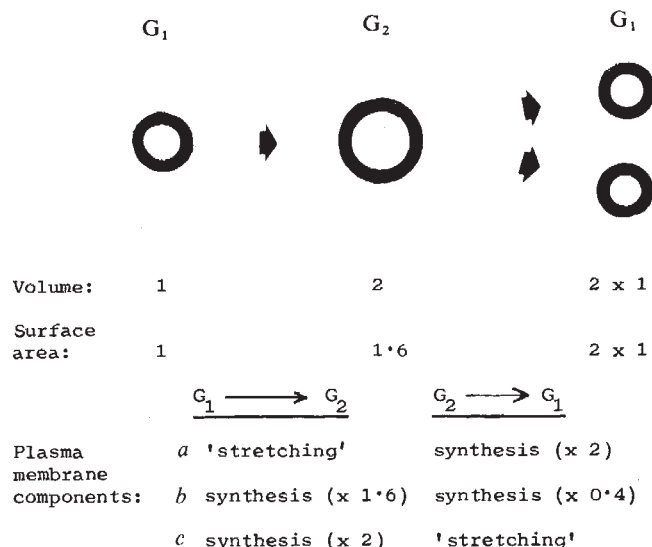


Fig. 1 Models of plasma membrane assembly during the cell cycle.

between G₂ and the next G₁ period, that is during mitosis (Fig. 1). Provided cell shape remains unaltered during growth, the deficit in surface area is approximately 0.4 for other shapes (for example, a flat disk) also. Only when growth is unidirectional, as in bacteria, does the deficit approach zero. By 'stretching' (Fig. 1) we do not wish necessarily to imply a 'ballooning' mechanism. An unfolding of previously-formed convolutions or ruffles¹⁹ is equally possible. Electron microscopic investigations are in progress to elucidate these alternatives.

In order to distinguish between the three possible mechanisms (Fig. 1a-c), we have now measured the content of the components of the plasma membrane, relative to the rest of the cell, during the cell cycle.

Cultured mouse mastocytoma cells (P815Y) and virally-transformed hamster fibroblasts (NIL-2HSV) were exposed to a pulse of ³H-thymidine before separation on a zonal rotor. Cells were allocated to a particular position in the cell cycle on the basis of (1) amount of ³H-thymidine incorporated, that is, ³H-DNA synthesis, (2) content of DNA and (3) cell size (Fig. 2); like P815Y cells²⁰, NIL-2HSV cells have rather long G₁ and S periods and a short G₂ period. Several runs were carried out with each line and cells at particular stages were pooled and disrupted by nitrogen cavitation. Nuclei were removed by centrifugation and the supernatant separated into mitochondria, endoplasmic reticulum and plasma membrane by high speed zonal centrifugation through a sucrose-dextran gradient^{13,14}. NIL-2HSV cells were used for the measurement of some enzymes because P815Y cells contain exceptionally low amounts (for example, 5'-nucleotidase); conversely, P815Y cells were used to measure carbohydrate content because of a more extensive study in progress (M. C. B. S. and C. A. P., unpublished).

Major Components

Figure 3 shows that the yield of plasma membrane protein, in terms of total cellular protein, is constant between G₁ and G₂ and therefore reflects a gradual doubling⁶ in plasma membrane protein during interphase. The possibility that plasma membrane protein includes protein adsorbed from the growth medium has to be borne in mind. Polyacrylamide gel electrophoresis does not reveal major changes in the pattern of plasma membrane proteins between G₁ and G₂. The ratio of plasma membrane phospholipid to protein remains fairly constant (Fig. 3), and therefore phospholipid, like protein, is inserted gradually throughout interphase.

In the case of carbohydrate, there is a slight fluctuation in ratio (Fig. 3), indicating a somewhat greater rate of synthesis and insertion during G₁, followed by a relative decrease, the ratio of carbohydrate:protein being restored in G₂. Measurement of individual sugars shows little variation in content of mannose, galactose or glucose during the cell cycle; fucose seems to be added predominantly in early G₁, glucosamine in late G₁, and sialic acid in late S-G₂. This is compatible with other studies^{21,22} showing that mitotic cells contain relatively more sialic acid than do cells in interphase. Fractionation of cellular carbohydrates into glycolipids, gangliosides and glycoproteins confirms these trends in showing an overall increase of each species during interphase (M. C. B. S. and C. A. P., unpublished).

We may conclude that the bulk of plasma membrane components increases during interphase and that the amount present in G₂ is approximately double that in G₁. In other words mechanism c of Fig. 1 is operative. One cannot, however, entirely dismiss mechanism b on the present evidence alone. Studies with cells actually proceeding through mitosis are currently being carried out to confirm this point. It is clear that mechanism a, suggested by earlier observations on bacteria^{23,24} or on animal cells synchronised by treatment with chemical inhibitors^{25,26}, is unlikely. Discrepancies arising from the use of chemically synchronised cells have frequently been documented (see, for example, ref. 27). Mechanism c is compatible with the observation that the concentration of membrane particles as revealed by freeze-fracture is maximal just before mitosis, after which the concentration drops rapidly to reach a minimum some time in G₁ (ref. 28). Mechanism c is also consistent with the proposition that cytokinesis is essentially a physical, contractile process in animal cells²⁹. It differs in that regard

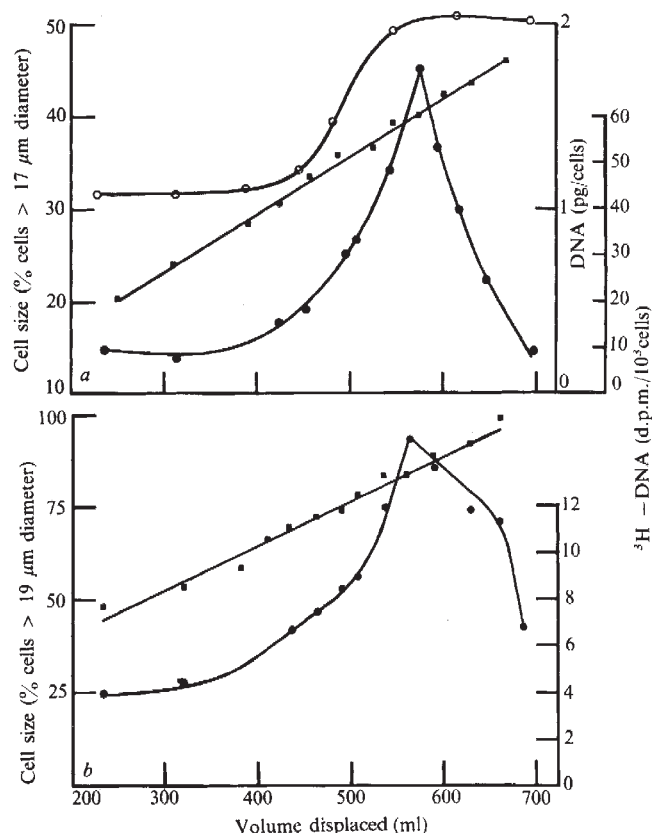


Fig. 2 Separation of cells by size. a, P815Y or, b, NIL-2HSV cells (10^6 - 10^7 ml⁻¹) were exposed to ³H-thymidine (1-2 μCi ml⁻¹) for 30-60 min, washed and separated by low-speed zonal centrifugation⁶. ³H-DNA (●); total DNA (ref. 52) (○); and cell size (ref. 6) (■) were measured.

from mucopeptide wall formation in microbes, in which septal growth is probably accompanied by net synthesis³⁰.

Minor Components

When the activity of an enzyme just doubles during the cell cycle, it is reasonable to assume that the increase reflects a net synthesis of enzyme molecules^{12,31}. This is the case with 5'-nucleotidase (Fig. 4a), though with chemically-synchronised cells a different result has been obtained³². When the activity fluctuates³³, as in the case of Na⁺/K⁺-ATPase (Fig. 4b) or adenyl cyclase (Fig. 4c), activation or turnover is superimposed on net synthesis. We have not yet distinguished between these two alternatives, but in other systems, turnover (involving temporal separation of synthesis and degradation) has been shown to occur³⁴.

The significance of the increased activity of Na⁺/K⁺-ATPase in late interphase (Fig. 4b) is not clear. It may be related to ionic fluctuations³⁵ which may affect volume and hence density³⁶ or which may control intracellular processes such as DNA synthesis³⁷; alternatively the enzyme may be sensitive to surface changes (see ref. 38) that occur during the cell cycle. In that regard it is interesting to note that the activity of the Na⁺/K⁺-insensitive ATPase behaves like that of 5'-nucleotidase. Fluctuations in a Ca²⁺-activated ATPase have been related to nuclear events during the cell cycle³⁹. The fact that Na⁺/K⁺-ATPase activity is restricted to the plasma membrane at all stages of the cell cycle (Table 1) means that significant amounts of enzyme do not accumulate at the site of synthesis (presumed to be the endoplasmic reticulum). In other words, insertion of components into the plasma membrane appears to follow closely upon synthesis.

The variation in activity of adenyl cyclase (Fig. 4c) does not agree with results obtained with chemically synchronised cells⁴⁰ in that high activity in mitotic cells is not apparent. Adenyl cyclase activity assayed in the absence of fluoride shows the same trends as those depicted in Fig. 4c. Our

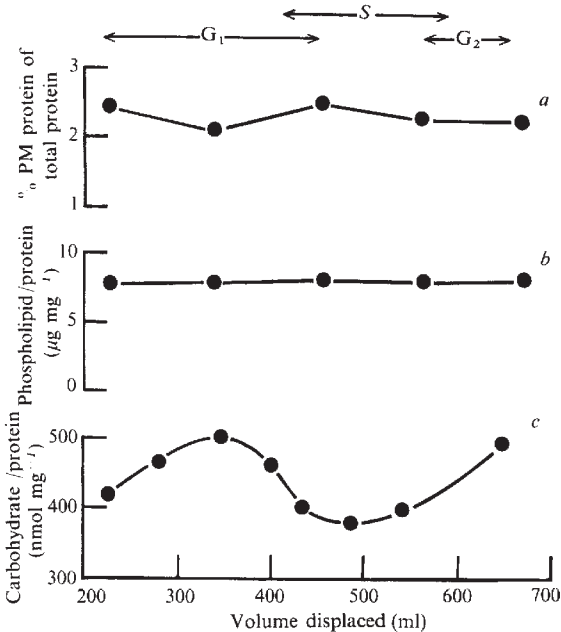


Fig. 3 Content of plasma membrane components during the cell cycle. NIL-2HSV (a and b) or P815Y (c) cells were separated by low-speed zonal centrifugation and pooled fractions disrupted by nitrogen cavitation. Plasma membrane (PM) was isolated by high-speed zonal centrifugation¹³ and the content of, a, protein⁵³, b, phospholipid phosphorus⁵⁴ and, c, carbohydrate (sum of individual sugars separated by gas-liquid chromatography⁵⁵) measured. The periods of the cell cycle, based on Fig. 2, are indicated.

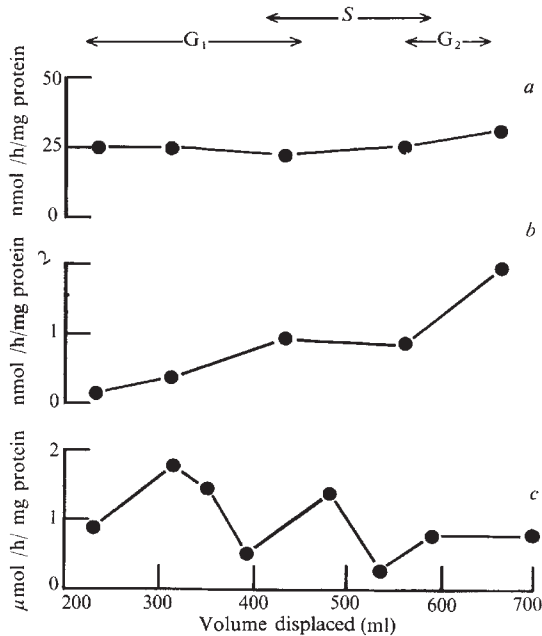


Fig. 4 Activity of plasma membrane enzymes during the cell cycle. NIL-2HSV (a and b) or P815Y (c) cells were separated by low-speed zonal centrifugation and pooled fractions disrupted by nitrogen cavitation (a and b) or by freeze-thawing (c). The activity of, a, 5'-nucleotidase⁵¹ and, b, Na⁺/K⁺-ATPase⁵¹ in plasma membrane isolated by high-speed zonal centrifugation, or of, c, adenyl cyclase in the presence of 10 mM fluoride⁵⁶ in total cell debris, was measured; in the case of adenyl cyclase, values are means of two separate determinations. The periods of the cell cycle, based on Fig. 2, are indicated.

results fit better with the observation⁴¹ that the intracellular content of cyclic AMP reaches a peak in G₁, with a second peak before mitosis. A decreased concentration of cyclic AMP in mitosis relative to interphase has also been observed by Burger *et al.*⁴². It is, however, by no means obvious that levels of adenyl cyclase and cyclic AMP are necessarily related⁴². Moreover in the present experiments, total adenyl cyclase activity was measured, and independent fluctuations in a nuclear enzyme^{43,44} would complicate the picture. It is therefore premature to speculate on possible roles of adenyl cyclase in triggering specific events during the cell cycle.

Table 1 Subcellular Distribution of Na⁺/K⁺-ATPase during Cell Cycle

Fraction	% in plasma membrane
1	95
2	92
3	90
4	85
5	90

NIL-2HSV cells were separated by low-speed zonal centrifugation⁶ and five fractions (corresponding to G₁→S→G₂ periods) disrupted by nitrogen cavitation, centrifuged to remove nuclei, and the supernatant separated into mitochondria, endoplasmic reticulum and plasma membrane by high-speed zonal centrifugation¹³. The content of Na⁺/K⁺-ATPase was assayed⁵¹ and the activity in plasma membrane expressed as a percentage of the total in the various organelles.

The expression of H-2 histocompatibility antigens, generally accepted as plasma membrane components, has been measured by immune cytotoxicity and found to be at a minimum in S (ref. 15). To investigate the reason for this effect, we have titrated the number of antigenic sites

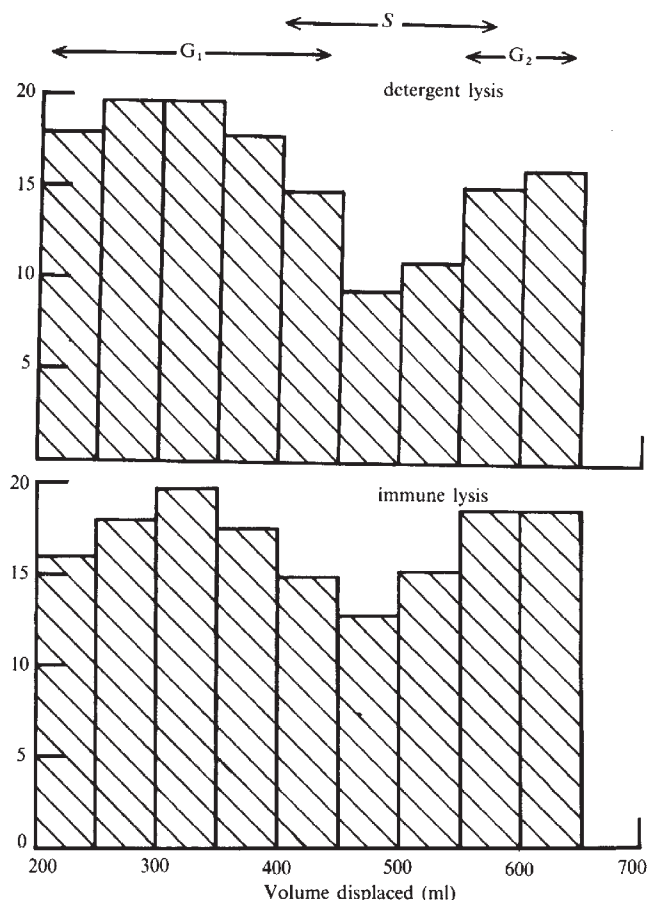


Fig. 5 Sensitivity to lysis during the cell cycle. P815Y cells ($2 \times 10^7 \text{ ml}^{-1}$) were incubated with $\text{Na}_2^{51}\text{CrO}_4$ ($10 \mu\text{Ci ml}^{-1}$) for 40 min at 37°C , washed three times and separated by low-speed centrifugation. Pooled fractions were exposed to 0.004% Triton X-100 or 2% anti-H-2 serum plus complement¹⁵ in Tris-buffered (50 mM, pH 7.2) saline for 40 min at 37°C , spun, and radioactivity in supernatant and pellet was measured with a γ -scintillation counter. Sensitivity to lysis is expressed as the % of total ^{51}Cr in cells that is released. The periods of the cell cycle, based on Fig. 2, are indicated.

with ^{125}I -labelled antibody and have also assessed the number of sites by competition for antibody in the cytolytic assay⁴⁵. Both results show an increase in antigenic sites during early interphase. The decreased expression during S is therefore unlikely to be due to 'masking'⁴⁶ and must reflect some other cause.

One possibility is that interphase cells are less susceptible to immune cytolysis because of a non-specific decrease in fragility, and we accordingly measured the ease of lysis brought about by detergents, hypotonicity or freeze-thawing. In each case we observed (Fig. 5) a minimum of fragility during S, which matches the minimum of antigenic expression at this time¹⁵. It is also in keeping with the model proposed for plasma membrane assembly (Fig. 2c), in so far as mitotic and some G₁ cells are likely to be more fragile than other cells; this might explain the greater sensitivity of mitotic cells to virally-induced fusion⁴⁷. It is of course possible that there are additional reasons for the reduction in immune cytolysis during interphase; the decreased expression of H-2 antigens as measured by immunofluorescence⁴⁸, for example, cannot be attributed to this cause.

Conclusions

Our results are compatible with a model for plasma membrane assembly (Fig. 2c) in which the major components are synthesised and inserted throughout interphase. During this time the surface area increases up to a point in G₂ when the volume of the cell (assuming a sphere) has doubled;

the concentration of membrane components per unit of surface area is restored to the original G₁ value during cytokinesis. A 'thickening' or folding of the plasma membrane¹⁹ during interphase may account for the increased resistance towards immunological and other cytolytic agents; such changes are distinct from alterations in microvilli and other surface structures¹⁹ that may be involved in cell-cell or cell-substratum interactions in other cell types. Specific components like 5'-nucleotidase, Mg^{2+} -ATPase, H-2 histocompatibility antigens or amino acid transport proteins⁴⁹ are likewise synthesised and inserted during early interphase; whether this is true of enzymes such as Na^+/K^+ -ATPase or adenyl cyclase that show fluctuations in activity remains to be seen.

When cells in the G₀ or resting state are stimulated to re-enter the growth cycle, there is generally an alteration in surface architecture⁵⁰. The rapidity of onset (well before mitosis) may be related to the fact that early interphase is the time at which many surface components are synthesised and inserted.

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LETTERS TO NATURE

PHYSICAL SCIENCES

Interpretation of the Hubble Diagram for Quasars

Setti and Woltjer^{1,2} have shown that the large scatter in the Hubble diagram for quasars (see Sandage³) may be greatly reduced if quasars with steep radio spectra and extended structures are considered alone. For this type of quasar there is a marked correlation between apparent optical magnitude and redshift, with a slope similar to that found for normal radio galaxies and the brightest galaxies in clusters.

The absence of such a correlation for quasars with flatter spectra may be attributed either to a broader dispersion in luminosity or to redshifts in these quasars, which are intrinsic to the source rather than a measure of cosmological distance. Although Setti and Woltjer prefer the explanation of luminosity dispersion, it is precisely this class of quasar for which Rowan-Robinson⁴ has presented independent arguments in favour of non-cosmological redshifts.

Here I extend the approach of Setti and Woltjer by considering in more detail the form of the radio spectra of a sample of the 166 quasars of known angular size and redshift (Miley⁵ and J. F. C. Wardle and G. K. Miley, to be published). Although the sample is slightly smaller than that used by Setti and Woltjer, the radio properties of the quasars included are considerably better determined.

For each source a radio spectrum has been compiled from measurements in the published literature, supplemented whenever possible by recent observations made at Jodrell Bank at 0.97 GHz (P. Haves, R. G. Conway and D. Stannard, to be published) and NRAO Greenbank at 2.7 and 8.1 GHz (J. F. C. Wardle and P. P. Kronberg, private communication). Each quasar has then been assigned a spectral classification according to the overall shape of its radio spectrum and the slope of the spectral curve evaluated at 3 GHz emitted frequency ($\alpha(3 \text{ GHz})$, defined in the sense that $S \propto f^\alpha$). Further details of this classification will be given as part of a comprehensive study of the radio polarisation properties of quasars which is being prepared by R. G. Conway, P. Haves, P. P. Kronberg, D. Stannard, J. Vallee and J. F. C. Wardle.

The three main categories considered here are: flat spectrum (thirty-two quasars), $\alpha(3 \text{ GHz}) \geq -0.3$; concave spectrum (twenty-six quasars), $\alpha(3 \text{ GHz}) < -0.3$, with a change of spectral index by $\Delta\alpha \geq +0.2$ in the range 0.5 to 5 GHz; steep spectrum (eighty-nine quasars), $\alpha(3 \text{ GHz}) \leq -0.7$ with a straight or convex spectrum.

This spectral subdivision has been chosen to reflect the degree of activity in quasars at radio wavelengths. The studies of Medd *et al.*⁶ suggest that the most violent radio variability is confined to the flat spectrum quasars, whilst the quasars with only a slight centimetre excess (concave spectrum) show only weak variability, and the steep spectrum quasars do not vary at all.

A formal classification has not been assigned to the 14 quasars in the sample with $-0.3 > \alpha(3 \text{ GHz}) > -0.7$ and a straight or convex spectrum. These sources are to be found among all three classes of activity, and presumably represent a borderline group which with more flexible splitting criteria could be redistributed amongst the major spectral categories. Five quasars with prominent maxima in the decimetre range also show no preferred degree of activity. As Medd *et al.* remark, this is rather surprising, as on the basis of many theories these sources might be expected to exhibit violent radio variability.

There is a striking correlation between spectral type and radio structure. 94% of the flat spectrum quasars have angular diameters of less than 3 arc s, whereas only 19% of the concave spectrum quasars and 20% of the steep spectrum quasars have such compact structures. Very long baseline interferometry⁷ suggests that many of the flat spectrum quasars remain unresolved on the scale of 10^{-2} arc s.

Table 1 Variation of Largest Angular Size with Redshift

Redshift range	Median LAS (arc s)	
	Concave spectrum	Steep spectrum
$z < 0.5$	40	55
$0.5 \leq z \leq 1.0$	15	20
$z > 1.0$	4	10

Both the concave and steep spectrum quasars show the decrease of largest angular size (LAS) with redshift which was first reported by Miley⁵. Although the data show considerable scatter (see ref. 5), there is a tendency for the median LAS of the concave spectrum quasars in each redshift range to be slightly smaller than that of the steep spectrum quasars (Table 1). In addition to this extended structure, the concave spectrum quasars frequently possess a compact radio component which is coincident with the optical nucleus and is responsible for most of the radiation at high frequencies. This component exhibits many of the properties commonly associated with the flat spectrum quasars.

Optical data for the quasars have been taken from the compilations of Setti and Woltjer² and De Veny *et al.*⁸. The Hubble diagram for the steep spectrum quasars in the present sample is similar to that presented by Setti and Woltjer^{1,2}, and shows a significant correlation between apparent V magnitude and redshift. As these authors suggest, the composite Hubble diagram for quasars of other spectral types does indeed show considerable scatter (Fig. 1), but if the quasars with flat spectra are considered on their own then there is again a marked correlation between apparent magnitude and redshift (Fig. 2).

The data for both the steep and flat spectrum quasars are consistent with a Hubble slope of 5 mag per decade of redshift. Although such a slope is not conclusive evidence for cosmological redshifts⁹, it is the value predicted on a Friedmann cosmology with $q_0 = +1$ and no luminosity evolution. Assuming this cosmology there is an important difference between the two types of quasar in that the mean absolute magnitude of the flat spectrum quasars is some 0.8 mag brighter than that of the steep spectrum quasars (with $H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$, the respective values are $-26.5 \pm 0.2 \text{ mag}$ and $-25.7 \pm 0.1 \text{ mag}$).

The Hubble diagram for quasars with concave spectra is shown in Fig. 3. It is not clear why this should be the only major class of radio quasar which fails to show a significant Hubble relationship. One possible explanation for the apparent steepness of the correlation between magnitude and redshift could be luminosity evolution in the sense that the high redshift quasars with concave spectra have systematically greater luminosities than those at low redshift.

The concave spectrum quasars possess a further optical peculiarity in that seven out of the twenty-six sources (27%) have prominent absorption features in their optical spectra, whereas the corresponding figures for the flat and steep spectrum quasars are four out of thirty-two (12%) and nine out of eighty-nine (10%), respectively. This presumably reflects the recent expulsion of material from the active nuclei of these quasars.

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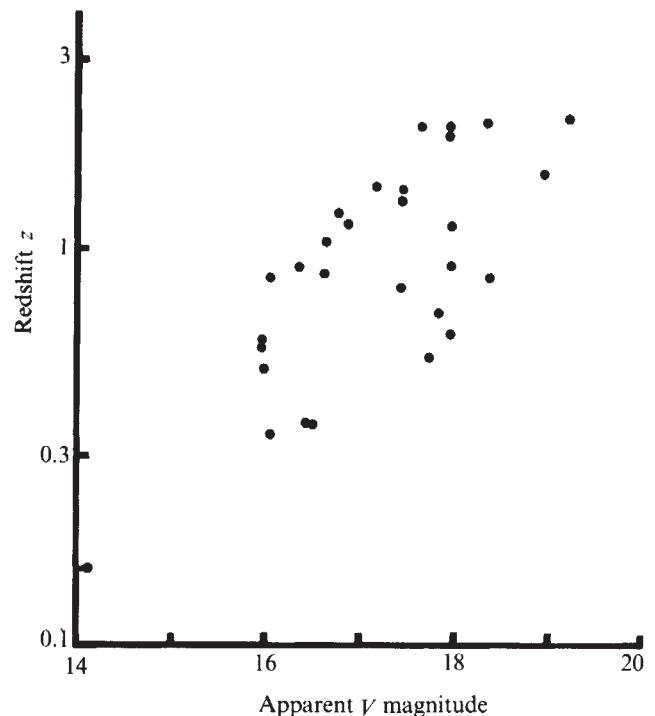


Fig. 2 Hubble diagram for quasars with flat radio spectra.

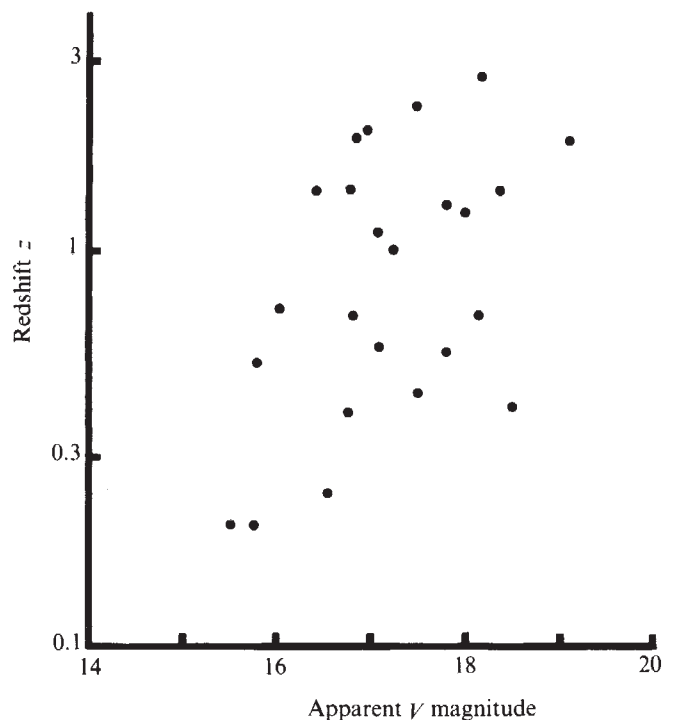


Fig. 3 Hubble diagram for quasars with concave radio spectra.

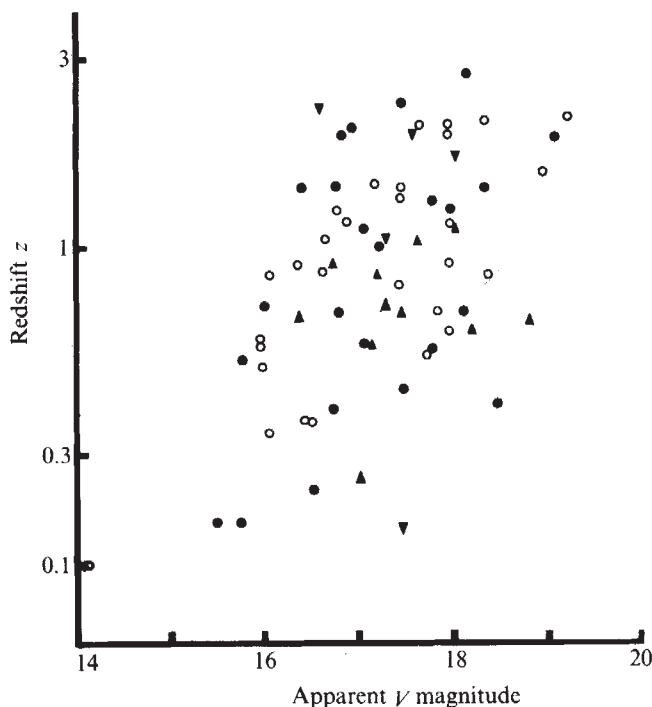


Fig. 1 Hubble diagram for quasars in the sample with measured V magnitudes and non-steep radio spectra. The flat spectrum quasars are represented by open circles, the concave spectrum quasars by filled circles, the straight spectrum quasars by triangles and the quasars with a single decimetric maximum by inverted triangles.

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Median Valley Refraction Line, Mid-Atlantic Ridge at 37° N

THIS communication describes the results of a reversed seismic refraction line carried out with explosives and seabed receivers in the median valley of the Mid-Atlantic Ridge during July and August 1973. The work was part of a detailed investigation of a crestal area of the Mid-Atlantic Ridge south-west of the Azores by the Franco-American Mid-Ocean Undersea Study (FAMOUS) group.

There seem to be very few published results of seismic refraction lines shot in the median valley of the mid-ocean

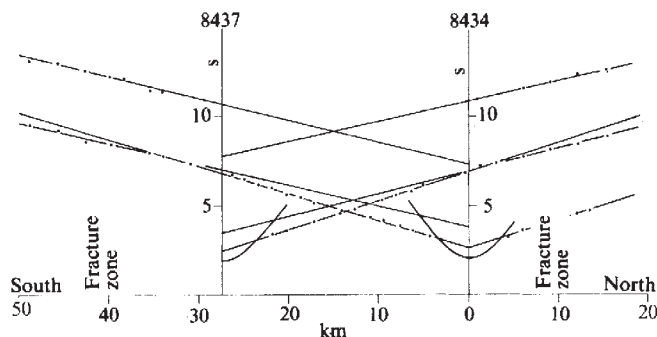


Fig. 2 Time-distance diagram of the two refraction lines. Points based on a multiple of the faster first arrivals are shown, but points from multiples of the slower first arrivals have been omitted. The curved lines were fitted to the direct water waves. See Table 1 for parameters of the straight lines.

ridge system¹⁻³. Such observations are necessary to provide constraints for models of ocean-crust genesis at mid-ocean ridges. The scarcity of seismic information about the near-surface structure beneath the axes of those mid-ocean ridges which have median valleys may be partly due to the remoteness of such regions but it is probably also a result of the difficulty of shooting conventional refraction lines there. The median valley in the FAMOUS area, for example, is less than 4 km wide except near the broad fracture zone valleys which offset it. It is difficult to prevent free-floating sonobuoys from drifting outside such a narrow target zone while a refraction line is being shot. The seabed recorders used in the present work, however, were free-fall pop-up devices⁴ which remained anchored to the seabed during the experiment so that the receiver positions remained fixed during each line.

Two refraction lines (Discovery stations 8434, 8437) were shot in opposite directions along the axis of the median valley in the FAMOUS area between two fracture zones (Fig. 1). Here the median valley is straight but rather short. Consequently some of the shots were fired over the wider parts of the median valley where it merges with the fracture zones or even over the fracture zone valleys themselves. Charge sizes were between 5 and 200 pounds for the first line and were fired at ranges up to 50 km from the receiver. Because of the strong arrivals thus obtained charges of only 5 or 25 pounds were used for the second line which was shot to a range of 43 km. The method of calculating horizontal range and travel time for the seabed receivers has been described elsewhere⁴. The range calculations made use of contemporary velocimeter information obtained nearby. Because of seafloor relief along the refraction lines the

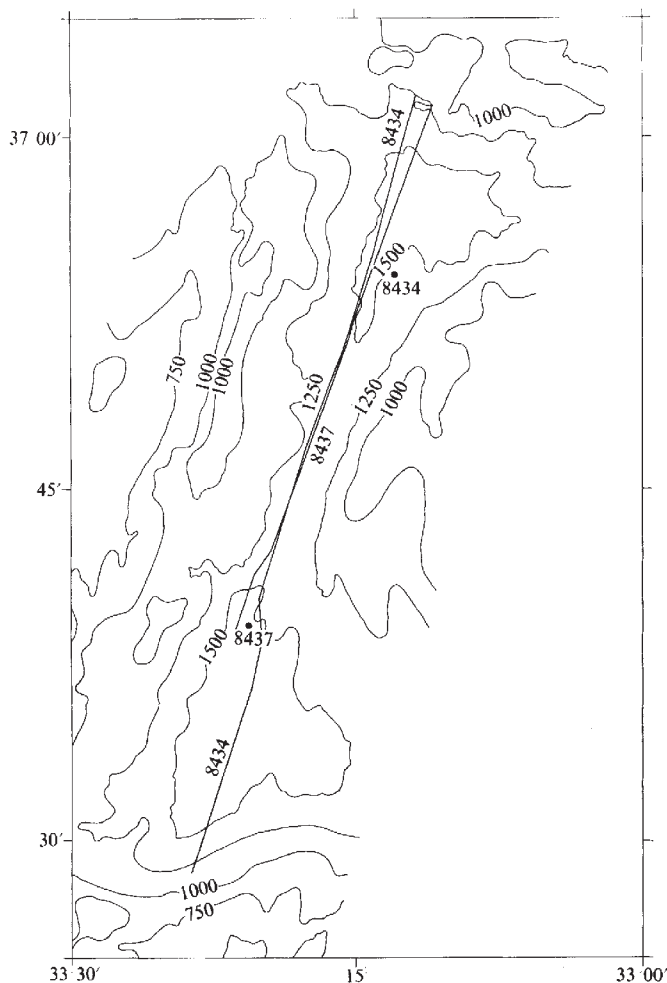


Fig. 1 Bathymetric chart of the median valley in part of the FAMOUS area showing the seismic refraction lines reported here; contours in uncorrected fathoms (from an unpublished chart produced by the Woods Hole Oceanographic Institution, courtesy of J. D. Phillips). The receiver position for each station is shown by a dot.

Table 1 Lines Obtained by Least-squares Fitting

Station	Velocity (km s ⁻¹)	Intercept (s)	N
8434 (south)	6.47 ± 0.10	2.66 ± 0.04	15
	8.12 ± 0.40	3.59 ± 0.25	6
	(7.83 ± 0.53)	(7.20 ± 0.36)	7
8434 (north)	6.12 ± 0.36	2.69 ± 0.09	7
8437	6.29 ± 0.10	2.61 ± 0.05	13
	8.19 ± 0.38	3.72 ± 0.22	4
	(8.47 ± 0.81)	(7.70 ± 0.43)	4
All data	6.37 ± 0.07	2.71 ± 0.02	35
	8.16 ± 0.06	3.00 ± 0.08	10
	(8.02 ± 0.44)	(7.46 ± 0.27)	11

Errors are standard errors; N is the number of points on which each least-squares line is based. Results between parentheses are based on a multiple of the first arrival (see text).

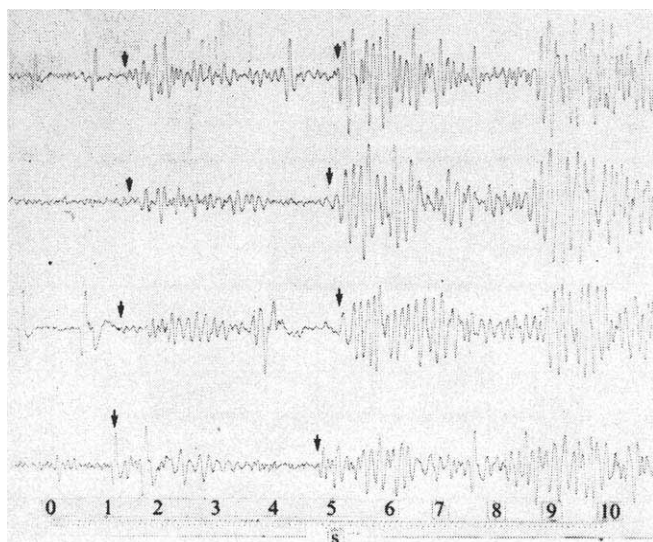


Fig. 3 Traces obtained from the seabed hydrophone for the four most distant shots of station 8437; shot-to-receiver range increases from top to bottom of the figure. The traces have been aligned so that a vertical line corresponds to a velocity of 8.0 km s^{-1} . $\downarrow$, Arrivals used to determine the velocity and intercepts of the second refractor. The occasional noise spikes are probably due to the acoustic transponder on the seabed equipment being triggered by local seismic noise. The records obtained at station 8434 were generally of better quality on account of the larger shot sizes.

travel times of ground waves were also corrected to the 1,700 fathom datum (3,193 corrected metres) assuming a basement velocity of 5.5 km s^{-1} . The resulting time-distance diagram is shown in Fig. 2 and the lines obtained by least squares fitting are shown in Table 1.

Table 1 and Fig. 2 show a well determined first refractor with a velocity between 6.12 and 6.47 km s^{-1} . The velocities and intercepts of the second refractor are less precisely determined essentially because they are based on fewer first arrivals than the first refractor. This is especially true of station 8437 where only four arrivals had the higher velocity and one of these had a poorly determined onset because of noise. It was possible to obtain independent confirmation of the existence of the second refractor, however, by considering multiples of the first arrivals due to a sea surface, or possibly a seabed, reflection. These arrivals, when observed at the seabed, are generally much greater in amplitude than their corresponding first arrival (Fig. 3). A similar procedure was carried out for station 8434.

It is particularly noticeable that the critical range beyond which first arrivals from the second refractor appear coincides at both stations with the deepest part of the cross-cutting fracture zone valley. It might therefore be argued that the arrivals with an apparent velocity of 8.2 km s^{-1} are actually due to a change in structure as the fracture zone is crossed, such as an upward dip of the first refractor. The northern half of station 8434, however, shows that this cannot be, since a normal first refractor velocity was observed there for arrivals passing across the fracture zone.

Statistically, since no measured velocity or intercept for stations 8434 and 8437 differs significantly from others in the same set all these values are assumed to be estimates of the same parameters. Thus best estimates of the velocity and intercept of each refractor were obtained using the reciprocal of the square of the standard error to weight each observation (Table 1). In practical terms this statistical argument is the same as making the assumption that both refractors are horizontal.

It is readily apparent from a comparison of the observed and expected intercepts that the 6.37 km s^{-1} refractor does not outcrop at the seabed nor is it possible that a 4 or 5 km s^{-1} bed overlies it since then seabed arrivals should have been seen as first arrivals. If the ground wave arrival at shortest range is attributed to a seabed refractor then the calculated velocity of this refractor (3.26 km s^{-1}) represents a maximum for the seabed. Actually a 2.8 km s^{-1} seabed velocity was assumed, for the purpose of calculating a structure, since this velocity was observed about 30 km west of the median valley on another line shot with the seabed receivers.

Table 2 Mean Structure Beneath the Median Valley

Layer	Velocity (km s^{-1})	Thickness (km)	Depth of top (km)
1	1.50	3.19	0
2	2.80^*	1.00	3.19
3	6.37	4.78	4.19
4	8.16	—	8.97

* Assumed velocity.

The calculated structure is presented in Table 2. This structure differs from that normally obtained in ocean basins only in the velocity of the seabed material, in the slightly lower velocity of the 6.37 km s^{-1} layer. There is no evidence of a velocity in the range normally attributable to Layer 2 but the topmost layer, which probably represents poorly consolidated or fractured volcanic material, may correspond to Layer 2A of Talwani *et al.*⁵. The velocity of the first refractor is remarkably close to that observed in the axial trough of the Red Sea³ out to a range of 45 km, but otherwise the observed velocities differ from earlier median valley lines^{1,2}.

I shall not discuss these results extensively here but broadly it can be said that a typical Layer 3 exists over a normal velocity upper mantle. The anomalous 7.4 km s^{-1} axial upper mantle of Le Pichon *et al.*² and Ludwig *et al.*⁶ is not observed. It seems evident that mantle material, which in this case could conceivably represent the top of the asthenosphere, is no closer to the seabed beneath the FAMOUS area than it is elsewhere in the North Atlantic. The mantle velocity, although not precisely determined, appears to be higher than might be expected from a mixture of olivine *b* and *c* crystal axes, or even *c* axes alone, aligned along the median valley⁷, as required by the models of Francis⁸ and Whitmarsh⁹ for generating upper mantle anisotropy, taking into account the expected temperature and pressure (about $1,000^\circ \text{C}$, 2 kbar)¹⁰ at the base of the crust beneath the median valley. It is also noticeable that arrivals which have travelled across the fracture zones at the top of the 6.37 km s^{-1} layer do not exhibit any clear travel time anomalies.

This work forms part of a larger seismic study of the FAMOUS area which will be published in detail at a later date.

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Attainment of Gigavolt Potentials by Magnetic Insulation

THE principle of my idea can be explained by Fig. 1, which shows a cross section through the proposed machine. The machine has two concentric conductors of toroidal symmetry which are placed within a toroidal magnetic field coil producing a magnetic field directed along the circular toroidal ring axis and varying in time. The space inside the inner conductor and in between the inner and outer conductor is a hard vacuum. The inner conductor is assumed to have a minor radius of r_i and the outer conductor a minor radius of r_o .

The inner conductor is not permitted to have any physical support in relation to the outside structure and thus has to be levitated. This can most easily be done by making the inner conductor or certain parts of it from a ferromagnetic substance. A properly applied auxiliary external feedback-controlled magnetic field coil, not shown in Fig. 1, can then keep the inner conductor stable in its position. The external conductor is surrounded by a toroidal magnetic field coil to be fed by a high current generator.

Both the inner and the outer conductor have a non-conducting gap. If the external coil is magnetised by the high current generator the magnetic field created can flow freely through these gaps first into the space between the outer and inner conductor and then into the space within the inner conductor. As a result the whole space inside the toroidal magnetic field coil will be filled with magnetic field.

If a cathode is placed within the gap of the outer conductor, emitting thermionic electrons, and if the externally applied magnetic field rises in time, then these electrons will be attached to and carried by the magnetic field lines moving towards the inner conductor. After reaching the inner conductor the electrons will detach themselves from the magnetic field lines and will form a surface charge on the inner conductor. The outer conductor, on the other hand, will be charged positively. The inner and outer conductors thus form a coaxial capacitor which is charged by the mechanism described up to some electrostatic potential.

There are, however, two important differences between the proposed machine and an ordinary capacitor.

(1) The charging up of an ordinary capacitor is usually carried out by some external voltage. Since the maximum attainable voltages are limited by dielectric breakdown in insulators, the maximum voltage available for charging a capacitor is limited regardless of the breakdown limitations within the capacitor itself. In contrast, charging up in the proposed machine is done entirely inductively and within a vacuum, thus eliminating the need for a high voltage source.

(2) The maximum voltage attainable in an ordinary capacitor, again, is dictated by dielectric breakdown. But for the proposed machine the situation is governed by a different principle. The externally applied axial magnetic field rises in proportion to the radial electric field resulting from the charging of the inner conductor and is thereby directed perpendicular to the radial electric field and parallel to both conducting surfaces. In this case, as long as the axial magnetic field

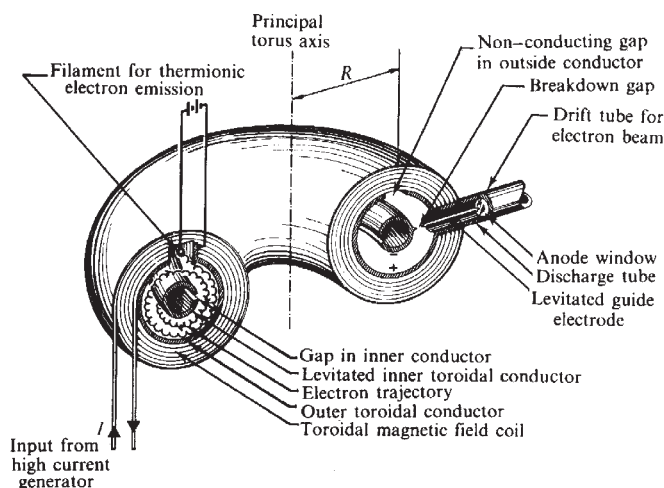


Fig. 1 Cross section through the toroidal machine described in the text.

strength $H >$ the radial electric field strength E (both measured in c.g.s. units) the magnetic field acts as an insulator with no dielectric breakdown limitations¹⁻⁴.

Because of the large magnetic fields attainable it is to be expected that the type of magnetically insulated capacitor described can be charged up to very high potentials. I assume, for example, that the magnetic field reaches a value of $H = 10^5$ gauss. The condition $E < H$ then means that $E < 3 \times 10^7$ V cm⁻¹. Therefore, for a gap between the inner and outer conductor which is assumed to be $r_o \approx r_i \approx 30$ cm the voltage of the capacitor would be $V \lesssim 10^9$ V. Furthermore, the energy stored in such a device would be considerable. If, for example, the volume occupied by the electric field is 1 m³ (10⁶ cm³), which is a rather modest volume if compared with conventional capacitors, then an energy $\epsilon \lesssim 40$ MJ could be stored. The discharge time τ of such a capacitor is of the order (volume)^{1/3}/velocity of light $\sim 3 \times 10^{-9}$ s. The discharge current is given by $I \sim \epsilon/V\tau \sim 10^7$ A. These values are far beyond the capability of any conventional machine operating with ordinary capacitors. Moreover such a machine can quite conceivably be built substantially larger, for example, by a factor of 100 in volume. This would lead to a stored electrostatic energy of several GJ. But even in this case the magnetisation of the field coil, and thus inductive charging, could still be carried out with a unipolar d.c. machine.

After the voltage has reached its peak value, whereupon E begins to exceed H , controlled breakdown will occur at a properly placed gap between a protrusion of the inner conductor and an auxiliary guide electrode in the form of a rod. As shown in Fig. 1 this guide electrode is placed in the centre of a coaxial conducting discharge tube. For this configuration the guide electrode has to be levitated, which again can be most easily achieved by making the guide electrode of some ferromagnetic material to be suspended by feedback-controlled external magnetic field coils. The coaxial conducting discharge tube is connected to, and at the same potential as, the outside toroidal conductor. During the charging up of the inner toroidal conductor, the guide electrode must be kept at the same potential as the outer conductor and the discharge tube. This will most probably happen automatically because of a small field emission current from the guide electrode onto the conducting discharge tube.

After breakdown has occurred in the breakdown gap, an intense beam of electrons will propagate along the surface of the guide electrode in a way similar to that observed by Bennett *et al.* for a dielectric rod⁵. What probably happens is that by action of the beam, some plasma will be formed on the surface of the guide electrode, cancelling the space charge of the electron beam emitted from the inner conductor. In propagat-

ing along the surface of the guide electrode the electron beam will then magnetically insulate itself against radial breakdown towards the coaxial tube. If, for example, the guide electrode has a diameter of $R=1$ cm and the electron current is 10^7 A, a self-magnetic field of $H \sim 2 \times 10^6$ gauss will be established by the beam, which is more than sufficient to ensure complete magnetic insulation of the beam against radial breakdown. If, for example, the voltage is $V \sim 10^8$ V an electric field of $E \sim V/r \sim 10^8$ V cm $^{-1} \simeq 3 \times 10^5$ e.s.u. is set up, so that clearly $E < H$.

After it reaches the end of the guide electrode the front of the electron beam faces the anode window. At the high energies contemplated the electron beam will pass through the anode window into the drift tube without any appreciable energy loss.

The power of the electron beam is $\sim IV = 10^{16}$ W. Furthermore, since the inductive charging can be done in a fraction of a second, the machine can work in a rapid sequence at very high average power levels that are unattainable in conventional particle accelerators.

The charging current I_c can be computed from the condition $I_c \tau_c = I \tau$ where τ_c is the charging time. If, for example, $\tau_c = 10^{-2}$ s it follows for the above values of I and τ that $I_c = 3$ A, which can easily be generated by thermionic emission. The power for the charging process is of the order $\sim I_c V = 3 \times 10^9$ W and could be drawn from a conventional a.c. power source. For large power levels a unipolar generator could be used.

The two most important applications of the machine described are for controlled thermonuclear fusion and for the collective acceleration of ions to ultrahigh energies.

(1) It is known that thermonuclear fusion can be achieved by utilising the concept of thermonuclear micro-explosions if the following conditions can be met: (a) an energy source must be available to deliver an energy of $\sim$ several MJ within 10^{-8} s; (b) the energy source must be capable of concentrating the energy into a volume which is a small fraction of 1 cm 3 ; (c) after concentration into such a small volume the energy has to be dissipated in heating up the thermonuclear material to be placed within the small volume.

A machine of modest dimension can easily meet the first condition. Since the energy is delivered in the form of an intense relativistic electron beam it can be concentrated into a very small volume if the strong self-magnetic forces acting on the beam are utilised. In this way the second condition can be met. The third condition can be very probably fulfilled by the collective beam-plasma two-stream instability¹. The energy and power which can be delivered by such a machine may even make possible the release of thermonuclear energy from the D-D reaction.

(2) The prospect of collective ion acceleration⁶ becomes especially interesting at the contemplated electron beam energies and intensities. The effect of collective ion acceleration can be most easily visualised in the following way. If an ion is placed in an intense stream of electrons, then by interaction with the beam it will eventually acquire the same γ value. But because, for example, a hydrogen ion has a mass $\simeq 1,800$ times larger than the electron, energies for the same γ values are larger by the same amount. Since the electron energies range up to 10^9 eV it follows that hydrogen ions could be accelerated up to $\sim 10^{12}$ eV = 1,000 GeV.

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Acceleration and Injection of Highly Relativistic Electrons during the August 7, 1972, Solar Flare

THE 3B flare of August 7, 1972, has been one of the largest of the present solar cycle and, thanks to the favourable conditions for particle propagation (the position of the flare on the Sun was 14° N, 37° W) and to the time of the day it occurred, one for which a large quantity of data is or will be available.

Mathews and Lanzerotti¹ have reported an observation of relativistic protons at Earth. Their results show that relativistic particles are accelerated and ejected into interplanetary space before the H α maximum phase is reached and in near coincidence with the white light phase.

Highly relativistic electrons from that flare have been observed in outer space (~ 33 Earth radii) by spacecraft. The characteristics of a former version of the detector have been described by Dilworth *et al.*². The present one has an energy threshold for electrons of about 20 MeV, taking into account the total efficiency of the instrument in the configuration it was on August 7, 1972. Figure 1 shows the time profile of the onset of the flare electrons. The integrated counting rate is transmitted every 32 s, but a statistically significant profile can be obtained only integrating over 128 s, which correspond to four telemetry frames. The first flare electrons are observed only between 1535 and 1537 UT, that is at least 5 to 10 min after the Calgary and Sulphur Mountain protons.

There are at least two instances in which MeV electrons and GV protons have been observed almost contemporaneously at Earth, in the well studied flare of July 7, 1966 (ref. 3) and on February 25, 1969 (ref. 4). The solar longitude of this latter event was also 37° W and the high energy electrons were observed by means of the same experimental technique². A time lag in the arrival time of flare-produced relativistic electrons and protons is not therefore a common feature of solar events.

Figure 2 shows schematically the time history of the relevant phenomena which occurred on August 7, 1972. The time scale is the time at the Sun (SUT) and particles are supposed to have travelled along the computed Archimedes spiral line¹. The GHz radio bursts⁵ and the hard X-ray emission⁶ are sure signs of relativistic electrons moving in the solar magnetic fields. Depending on the frequency, the radio burst rise times are of 11 to 15 min and the maximum intensity is reached at 1514 SUT. Hard X rays have rise times of about 8 min and a maximum at 1513 SUT. The time of maximum of the GHz radio bursts, of the hard X rays and of the white light flare¹ (this latter phenomenon indicating precipitation of accelerated protons and electrons and heating of the photosphere) all coincide within 2 min. The chromospheric H α flare, on the contrary, has a maximum at 1526 SUT (ref. 7), but this does not seem to be strictly connected with particle acceleration. The 4 GV protons leave the Sun at 1515 SUT. Acceleration of relativistic particles has therefore taken place before this time and from the radio and X-ray rise times we can conclude that it has lasted about 8 to 10 min. Unless unorthodox mechanisms are considered, this duration of

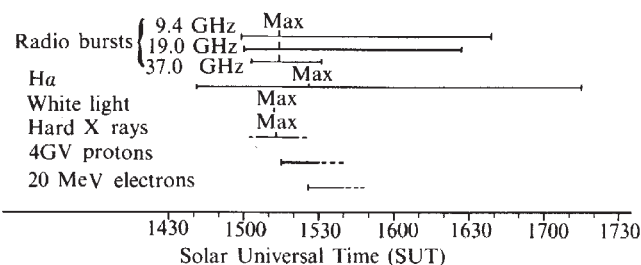


Fig. 1 Time profile of the onset of the ≥ 20 MeV electrons observed on August 7, 1972.

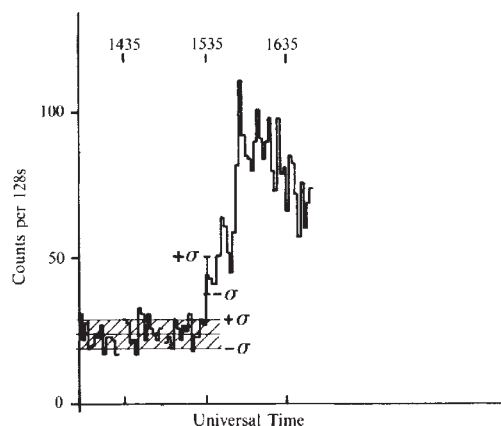


Fig. 2 Schematic time history of the main events of the August 7, 1972, solar flare.

acceleration is too long to produce the electrons observed at the Earth. Fürst *et al.*⁸ have analysed the 17 and 35 GHz bursts and find that the magnetic field in which the electrons radiate must be of the order of 1,000 gauss. Svestska⁹ has shown that there is a strict relation between the magnetic field, the duration of acceleration and the electrons high-energy cutoff. For a 1,000 gauss field, he computed a cutoff of 18 MeV for a duration of 1 min. This difficulty can be overcome by supposing that several accelerations (at least four) have taken place during the ~10 min rise time of the radio and X-ray bursts, each acceleration lasting less than 1 min. Evidence for this is supplied by the time profiles in the radio and X-ray frequency bands, since the rise to maximum intensity is not monotonous, but at least four peaks are identifiable, each with rise times of less than 1 min.

This multiple acceleration cannot, however, explain the time lag at the Earth between protons and electrons. If a very fine structure of the interplanetary magnetic field is not responsible for the delay in the arrival time of the first electrons, these must spend 5 to 10 min after acceleration in the solar corona, in a region where radiation energy losses are not large. The implication is that, since the times of acceleration and of injection into interplanetary space may not always coincide, care must be taken in applying the propagation theories to solar particle events. Furthermore, if the time delay in the onset of the relativistic electrons means that they spend this time in the solar corona, not only their injection time but also the longitude of injection can be different from that of the protons.

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Monocarboxylic Acids in Murray and Murchison Carbonaceous Meteorites

THAT carbonaceous meteorites contain organic substances has been known for more than a century, and during this time controversies developed concerning whether or not this organic material was a product of extraterrestrial life. Within the past few years studies of carbonaceous meteorites have provided solid evidence that certain organic compounds are indigenous and were most likely produced by non-biological, chemical syntheses¹⁻⁷. These studies have emphasised the occurrences of amino acids and hydrocarbons in two C2 carbonaceous chondrites, the Murray and the Murchison. We have now found in specimens of both of these meteorites straight and branched-chain monocarboxylic acids having two to eight carbon atoms. Although many of these acids are of biological significance, the distribution of compounds in these meteorites supports the proposition that they, like the amino acids and hydrocarbons, result from non-biological, chemical syntheses.

The outside fusion crusts of both meteorites were carefully removed. Interior pieces were finely ground in a mullite mortar with a pestle. A 6.1 g sample of Murray and a 5.3 g sample of Murchison were each processed separately using the following procedure. The pulverised sample was refluxed with 30 ml of methanolic potassium hydroxide (10:1 v/w) for 3 h, with stirring, in a 100 ml round-bottom flask. A reflux condenser with a drying tube containing potassium hydroxide pellets and Drierite was attached to the flask. After cooling to room temperature, the contents of the reaction flask were transferred and centrifuged in two 50 ml Teflon test tubes. The supernatant was decanted into a separatory funnel containing 30 ml of distilled water. The resultant alkaline solution, after three extractions with 15 ml portions of dichloromethane, was collected in a 100 ml round-bottom flask and evaporated to dryness under reduced pressure. Cold, concentrated hydrochloric acid was added to the solid residue until the resulting solution reached pH 1, while the flask and its contents were cooled in an ice-water bath. The acidified solution was extracted five times with 1 ml portions of dichloromethane. The combined extracts were dried over 0.5 g anhydrous sodium sulphate. The carboxylic acid content of this solution was determined by gas chromatography and by combined gas chromatography-mass spectrometry.

Identification of monocarboxylic acids in both the Murray and Murchison meteorites is based on (1) coincidence of gas chromatographic retention times between sample monocarboxylic acids and authentic standards, and (2) equivalence of mass spectra of the sample compounds with the mass spectra of standards obtained in this laboratory and from the literature^{8,9}. Interpretation of mass spectra of these monocarboxylic acids is relatively straightforward¹⁰. The following ten monocarboxylic acids are securely identified based on the criteria given above: acetic acid; propanoic acid; 2-methylpropanoic acid; butanoic acid; 3-methylbutanoic acid; pentanoic acid; 4-methylpentanoic acid; hexanoic acid; heptanoic acid; octanoic acid.

In addition five monocarboxylic acids are only tentatively identified because of the lack at this time of authentic standards with which to obtain gas chromatographic retention times. These compounds, however, have mass spectra which resemble published mass spectra⁸: 2,2-dimethylpropanoic acid; 2-methylbutanoic acid; 2-methylpentanoic acid; 3-methylpentanoic acid; 4-methylhexanoic acid.

Two of these compounds (2-methylbutanoic acid and 3-methylpentanoic acid) seem to be present in the standard as impurities (Fig. 1). The presence of two or three additional compounds (2,3-dimethylbutanoic acid, 2,2-dimethyl-

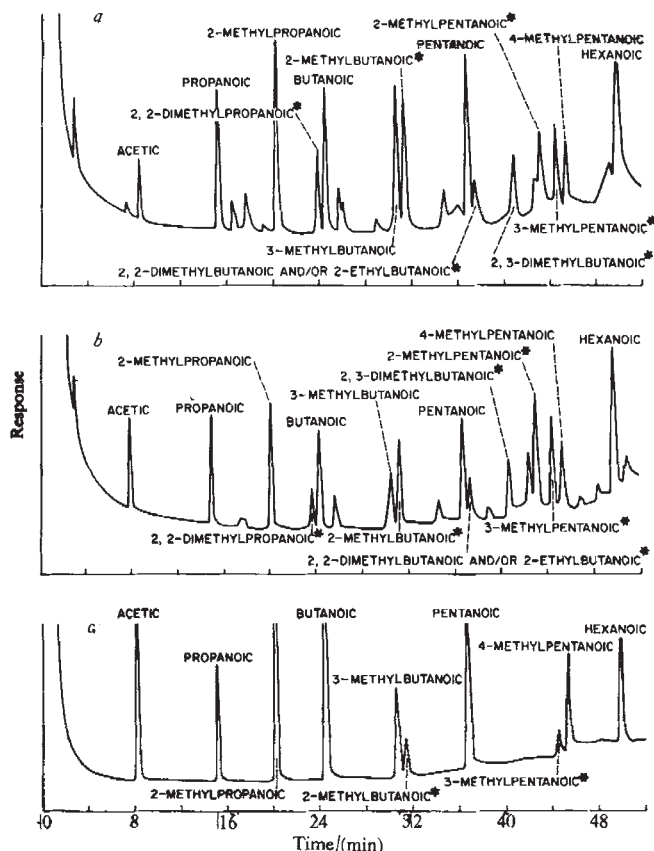


Fig. 1 Gas chromatograms of monocarboxylic acids in Murray (a) and Murchison (b) meteorites compared with a mixture of standard acids (c). *, Tentative identification. 2-Methylbutanoic acid and 3-methylpentanoic acid seem to be impurities in the standard. Chromatographic conditions: Perkin-Elmer 900 (flame ionisation) with stainless steel capillary column (46 m $\times$ 0.05 cm internal diameter) coated with UCON L8-550 x-H, PO₄ (ref. 11). Temperature programmed at 1° min⁻¹ from 70° to 120° C.

butanoic acid and/or 2-ethylbutanoic acid) is indicated based on rationalisations of their mass spectra. Figure 1 compares the gas chromatograms of the monocarboxylic acids recovered from both the Murray and Murchison meteorites with a standard. The chromatograms show compounds only to hexanoic acid. With the chromatographic conditions used, 4-methylhexanoic acid, heptanoic acid and octanoic acid had long retention times and showed peak broadening. The possible presence of monocarboxylic acids with more than eight carbon atoms is a subject of our continuing research.

The occurrence of short-chain monocarboxylic acids in carbonaceous meteorites has not been reported previously. But long-chain fatty acids, higher than about C₁₄, were reported to be present in the Orgueil meteorite by both Meinschein¹² and Nagy and Bitz¹³. In this earlier work even-carbon-numbered fatty acids dominated the mixtures and there was no mention of the occurrence of branched-chain fatty acids. Hayes¹⁴ suggests that the results may, in part, be accounted for by terrestrial, biological contamination. In our work we also looked for the long-chain fatty acids. Gas chromatographic evidence suggested the presence of tetradecanoic acid, hexadecanoic acid and octadecanoic acid (as methyl esters resulting from the esterification procedures used) in surface samples of Murchison meteorite. But no evidence could be found for these compounds when interior portions of the meteorite were studied.

The concentration of short-chain monocarboxylic acids recovered from the Murray and Murchison meteorites ranges from about 10 to 60 $\mu\text{g g}^{-1}$ for each individual compound.

This concentration is about an order of magnitude larger than the concentration of amino acids recovered from the same meteorites (but different specimens)^{1,3}. The state of the monocarboxylic acids within the meteorite samples is not known at present; they may occur as free acids or esters or possibly as salts.

In the Murray and Murchison meteorites the distribution of monocarboxylic acids is remarkably similar. Both straight and branched-chain monocarboxylic acids are present. In fact, all the possible monocarboxylic acid isomers containing two, three, four, and five carbon atoms are accounted for. Of the eight possible monocarboxylic acids containing six carbon atoms, at least five are present and perhaps seven can be accounted for. The presence of so many isomers of these low molecular weight, monocarboxylic acids is comparable to the similar isomeric distribution of amino acids having four and less carbon atoms². It seems evident that a random chemical synthesis must have been responsible for generating both populations of molecules. Whether a relationship exists between the two populations is not known at present.

The characteristic even-carbon-numbered predominance of natural, biological populations of monocarboxylic acids¹⁵ contrasts with the distribution of acids found in the meteorites (Fig. 1) wherein both even and odd-carbon-numbered molecules are about equally abundant, and branched-chain acids are as common as straight-chain acids. Clearly, the difference in distributional patterns between the acids in the meteorites and acids in biological materials rules out the remote possibility that the acids in the meteorite resulted from terrestrial, biological contamination.

The finding of these monocarboxylic acids in meteorites has important implications for chemical evolution. In synthesis experiments Miller¹⁶ formed formic, acetic and propanoic acids when a primitive-type Earth atmosphere was exposed to a dark discharge. Eck *et al.*¹⁷ predicted on theoretical grounds that monocarboxylic acids in the range considered in this paper (C₂ to C₆) could be formed inorganically under equilibrium conditions, and that there would be little difference in concentration between straight and branched-chain isomers. Our meteorite results support this prediction with regard to isomer distribution. Allen and Ponnamperna¹⁸ reported the production of C₂ to C₁₂ monocarboxylic acids in a methane-water mixture which was exposed to a semicorona discharge. The following acids were identified: acetic; propanoic; butanoic; 3-methylbutanoic; pentanoic; and 4-methylpentanoic. At carbon numbers greater than six, only branched-chain carboxylic acids were detected. Our meteorite studies suggest that the monocarboxylic acids found may have been generated by a naturally occurring, chemical synthesis; indeed, the results provide strong support for the chemical evolution theory.

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Pleistocene Human Occupation and Extinct Fauna in Cloggs Cave, Buchan, South-east Australia

A STRATIFIED and undisturbed occupation deposit containing stone and bone tools and a rich faunal assemblage has been discovered in a limestone cave at Buchan, in eastern Victoria (latitude 37° 31' S, longitude 148° 10' E). This is the first Pleistocene occupation site in which bone is preserved, yet found in eastern Australia.

Part of the deposit has been excavated, to a depth of 2 m, where massive slabs of rock fall were encountered. The lowest level excavated yielded extinct fauna, including a mandible *in situ* of the extinct giant kangaroo, *Sthenurus orientalis*. Immediately above the horizon containing extinct fauna were traces of human occupation, in the form of stone tools. Charcoal associated with the lowest tools was dated to 17,720 ± 840 BP (ANU-1044).

The tool assemblage compares very closely with that of the 8,000 yr-old levels of the Rocky Cape cave in northern Tasmania, excavated by Jones¹. Both assemblages comprise pebble tools, steep-edged scrapers and bone awls, all of which reflect the manufacture of skin rugs and of wooden implements such as spears.

The Buchan cave was apparently vacated about 8,000 yr ago, a date of 8,720 ± 230 BP (ANU-1001) having been obtained on charcoal from a hearth level only 15 cm below the present floor of the cave. The rock shelter outside the cave was utilised, however, in more recent times.

The vacation of the dark, but warm and dry, inner cave may have occurred in response to the climatic amelioration at the end of the Glacial Period, but the faunal evidence shows that there was a basic climatic and vegetational stability over the period represented by the cave deposit, that is, from before 18,000 BP to 8,000 BP. The species represented inhabit grassland, open woodland and dry sclerophyll forest habitats, together with wet grassy hollows and swampy alluvial flats such as are found along the Buchan River today.

Flotation techniques were used in processing the cave

deposit, and by this means some vegetable material such as leaves and wood was recovered. Coprolites were also found, and it has been possible to identify the species of grass eaten by the herbivores found at the site.

Work on Cloggs Cave thus has important implications for the study of the palaeoenvironment as well as for the pre-history of Australia, and is continuing under the aegis of the Australian Institute of Aboriginal Studies.

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BIOLOGICAL SCIENCES

Translation of Collagen mRNA from Chick Embryo Calvaria in a Cell-free System derived from Krebs II Ascites Cells

COLLAGEN is a helical molecule composed of three polypeptide chains (α chains) each with a molecular weight of approximately 95,000. The polypeptides are synthesised separately as precursor chains containing additional amino acids at the NH₂ terminal end¹⁻⁹. These pro α chains aggregate to form procollagen which is then secreted from the cell¹⁰. Procollagen peptidase removes the NH₂ terminal segment from the soluble procollagen and the collagen is then deposited in extracellular fibres¹¹.

Although there have been several recent reports of cell-free synthesis of collagen, these describe the continuation of collagen synthesis on pre-existing polysomes using disrupted cells from embryonic chick wings and legs^{6,7} and from L-929 fibroblasts¹². We describe here the preparation of mRNA from 15-d chick embryo calvaria, and its translation in a true heterologous system derived from pre-incubated Krebs II ascites cells. Unlike previous reports, our system depends on the addition of exogenous RNA for protein synthesis.

The level of functional mRNA in the total RNA extracted from the calvaria was determined by its ability to direct the incorporation of radioactive proline into trichloroacetic acid (TCA)-tannic acid-precipitable material in a cell-free system derived from preincubated Krebs II ascites cell extracts. Components of the cell-free system are listed in Table 1. Proline incorporation had a magnesium optimum of 3 mM and a broad potassium optimum with a peak at 55 mM. As has been previously noted¹³, low concentrations of EDTA stimulated incorporation. Ascorbic acid increased incorporation by 10% and was included routinely in the reaction mixture.

In a standard reaction, proline incorporation was linear for 30 to 40 min and gradually reached a plateau so that at 60 min the incorporation was 50–100 times greater than background (without added mRNA). The extent of incorporation was directly proportional to the amount of calvaria RNA added to the reaction mixture. We were unable to saturate the system with the calvaria RNA under the assay conditions used.

The Krebs II ascites system was developed by Kerr *et al.*^{14,15} and Mathews and Korner¹⁶. While they found that protein synthesis in the ascites system was independent

of exogenous tRNA, Aviv *et al.*¹⁷ observed dependence when exogenous tRNA was added.

After initial experiments in which we observed that exogenous tRNA had a slight inhibitory effect on the Krebs II system we increased the preincubation period of the ascites S30 extract. This increase lowered the background incorporation five-fold to 300 c.p.m. and made the extent of incorporation sensitive to the addition of tRNA (Table 1). Optimal tRNA stimulation was observed after 100 min of preincubation. The cause of ascites tRNA inactivation during the extended preincubation is unknown. Our findings indicated that differences in the preincubation procedure can account for the discrepancy in previous reports concerning the tRNA dependency of the Krebs II ascites system.

The protein synthesised was identified by subjecting the product to digestion by bacterial collagenase. The specificity of the enzyme was determined by its failure to digest a whole chick embryo extract labelled with ³H-tryptophan, an amino acid absent from collagen. By susceptibility to

Table 1 Effect of Increasing the S30 Extract Preincubation Time on tRNA Dependency

Pre-incubation time (min)	µg tRNA * added	TCA-tannic acid precipitated ³ H-proline (c.p.m.)	% of control
45	—	8,156	100
	7.5	6,678	82
	15.0	7,160	88
100	—	4,550	100
	7.5	8,390	184
	15.0	13,550	305
120	—	4,100	100
	7.5	7,700	188
	15.0	9,700	237

An S30 extract was prepared from Krebs II ascites cells as described¹⁶ except that the preparation was dialysed against buffer. The S30 extracts were prepared identically with the exception of the length of the preincubation period. RNA was prepared from the calvaria of 15-d embryonic chicks (Truslow Farms). The tissue was removed, placed in liquid nitrogen and ground to a fine powder in a mortar and pestle. The powder was suspended in 10 volumes of buffer containing 50 mM Na acetate, pH 5.0, 1 mM EDTA, 1% bentonite and 0.5% Sarkosyl and extracted at 50° C for 2 min with an equal volume of phenol: chloroform: isoamyl alcohol (50: 50: 1). The aqueous phase was re-extracted twice more. RNA was precipitated with two volumes of ethanol and 0.03 volumes of 4 M NaCl. The RNA was collected by centrifugation and dissolved in water at a concentration of 60 A₂₆₀ ml⁻¹ and stored in liquid nitrogen. The tRNA was extracted from 12-d embryonic chick wings and legs by the same method. The aqueous phase was precipitated with 2 volumes of ethanol and 0.1 volume of 20% K acetate. The RNA was collected by centrifugation, washed three times with 70% ethanol, and dissolved in 10 mM Na acetate buffer, pH 4.5, containing 1 M NaCl. The supernatant was chromatographed on DEAE by the method described³⁰. The tRNA was collected by ethanol precipitation, dissolved in 10 mM Na acetate buffer, pH 4.5, containing 10 mM MgCl and 0.2 M NaCl at a concentration of 30–60 A₂₆₀ ml⁻¹ and stored at –20° C. Concentration of RNA was estimated by A₂₆₀: 25 A₂₆₀ 1 mg ml⁻¹. A standard 50 µl reaction mixture contained 0.50 A₂₈₀ units S30 extract, 0.09 A₂₆₀ units tRNA, 0.08 A₂₆₀ units calvaria RNA, 16 µg denatured lathyrus chick collagen²⁸, 160 µg creatine phosphate, 8 µg creatine phosphokinase, 3.2 µg ascorbic acid and 3.2 mM Mg acetate, 85 mM KCl, 44 mM Tris-HCl, pH 7.5, 1 mM ATP, 0.16 mM GTP, 0.8 mM CTP, 0.13 mM EDTA, 4.6 mM 2-mercaptoethanol, 40 µM nineteen cold amino acids and 2 µM 3,4,³H-proline, neutralised (1.37 × 10⁴ c.p.m. pmol⁻¹). The reactions were incubated at 37° C for 60 min. A 200-fold excess of cold proline was added to the reaction mixture and incubation was continued for an additional 20 min to chase ³H-proline from prolyl-tRNA. A 1 ml sample of cold 10% TCA containing 0.5% tannic acid was added and the reaction mixture chilled. The samples were filtered on Millipore filters which had been soaked for 30 min in 5% TCA containing 4 mM proline. The filters were washed with cold 5% TCA containing 0.25% tannic acid, dried at 80° C for 30 min and counted in a toluene-Liquifluor cocktail in a Beckman scintillation counter.

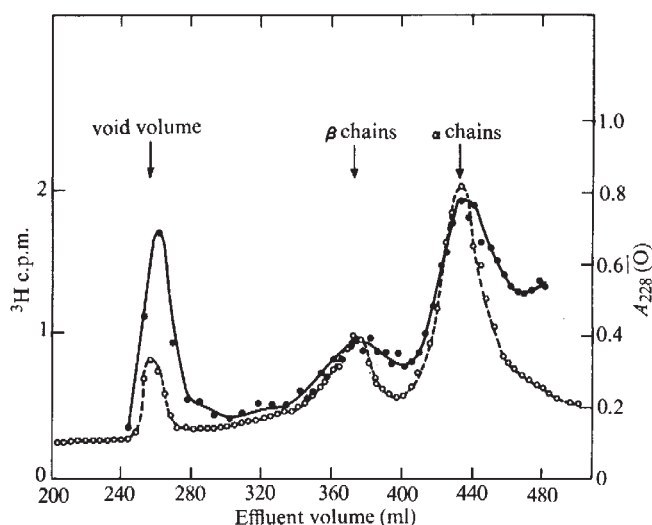


Fig. 1 Molecular sieve chromatography of the *in vitro* synthesised protein. A reaction mixture, thirty-fold the standard reaction (Table 1), was incubated for 60 min at 37° C. The precipitate formed during the incubation was collected by centrifugation (10,000g for 10 min) and dissolved in buffer (50 mM Tris-HCl, pH 7.5) containing 8 M urea and 10 mM mercaptoethanol. 5 mg of purified lathyrus chick skin collagen^{28,29} was added and the solution was heated for 30 min at 40° C. CaCl₂ was added to a final concentration of 1 M. The sample was applied to a 6% agarose column (1.5 × 200 cm) equilibrated with 50 mM Tris-HCl, pH 7.5, buffer containing 1 M CaCl₂. A Buchler peristaltic pump reduced the flow rate to 20 ml h⁻¹. Fractions (4 ml) were collected and the A₂₂₈ of each fraction was measured. Aliquots (1 ml) were counted in Aquasol (New England Nuclear) in a Beckman scintillation counter: (●) radioactivity; (○) A₂₂₈. The collagen molecule contains three polypeptide chains. Collagen of skin, bone and tendon contains two identical chains termed α₁, and a third chain which is a different gene product, α₂. The formula for the complete molecule is (α₁)₂α₂. The collagen of cartilage is composed of three identical chains, termed (α₁)₃. α chain dimers can be observed, and these are termed β chains. A β component may be composed of two α₁ chains (β₁₁), or of one α₁ and one α₂ chain (β₁₂).

collagenase digestion, it was estimated that 55% of the products synthesised in the *in vitro* system was collagen (Table 2).

A more rigorous identification of the protein product was effected by isolating the radioactive protein from a large scale reaction mixture. The reaction was terminated by the addition of EDTA to 50 mM, and immediately chilled. The precipitate which formed during incubation was collected by centrifugation and solubilised by heating to 40° C in buffer (50 mM Tris-HCl, pH 7.5) containing 8 M urea and 10 mM 2-mercaptoethanol. Samples of the supernatant and the solubilised precipitate were chromatographed separately on molecular sieve columns of 6% agarose. While no proteins with a molecular weight greater than 20,000 were present in the reaction supernatant, the solubilised precipitate contained three high molecular weight proteins (Fig. 1). Two of these radioactive proteins co-chromatographed with the α and β chain components of the chick carrier collagen used as markers.

CM-cellulose chromatography identified two proteins as α₁ and α₂ respectively, on the basis of their co-elution with chick carrier collagen (Fig. 2). Therefore, the calvaria RNA contained the messenger for both the α₁ and α₂ chains of collagen.

Several eukaryotic mRNAs have been translated in heterologous eukaryotic and prokaryotic cell-free systems^{18–26}. This suggests that there are no absolute species-specific or tissue-specific factors required at the translational level of protein synthesis. Our data are further confirmation of this hypothesis.

The molecular sieve chromatography demonstrated the

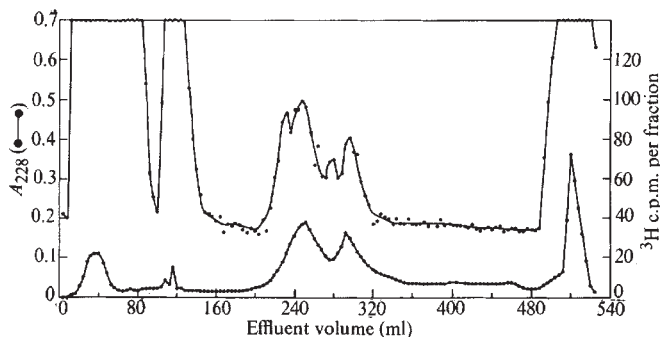


Fig. 2 CM-cellulose chromatography of the *in vitro* synthesised protein. Purified lathyritic chick skin collagen (20 mg) prepared as described previously was added to the dissolved precipitate formed in a large scale reaction (Fig. 1). The sample was heated for 30 min at 40° C and dialysed extensively against 0.04 M Na acetate buffer, pH 4.8 at 4° C. After heating the sample again it was applied to a CM-cellulose column (2.5 × 10 cm) equilibrated with the same buffer and eluted with a 400 linear NaCl gradient from 0.04 to 0.14 M and a final wash with 1 M NaCl in 0.5 M NaOH²⁹. Fractions (4 ml) were collected and the A_{228} and radioactivity of each sample were determined as in Fig. 1: (●) Radioactivity; (○) A_{228} . See Fig. 1 for an explanation of the $\alpha 1$ and $\alpha 2$ terminology.

presence of an *in vitro* synthesised protein as large as authentic chick α chains. The ion exchange chromatography on the CM-cellulose columns provided further evidence that authentic chick collagen had been synthesised. Proteins synthesised in the *in vitro* system co-chromatographed with the $\alpha 1$ and $\alpha 2$ chains of the marker chick collagen.

Pro α chains, the primary product of protein synthesis, have a molecular weight of 115,000⁴ and if present would have eluted from the agarose column at 410 ml. The protein eluting from the CM-cellulose in the region where pro $\alpha 1$ is usually observed just before the $\alpha 1$ carrier^{1,2} was too small to be precipitated in TCA-tannic acid. The pro α chains seem to have been converted to α chains during incubation. Previous studies with the polysome system¹³ and with intact calvaria²⁷ indicate rapid and extensive conversion of pro α chains to α chains. The pro α chains may have been degraded through the action of the specific procollagen peptidase¹¹ or a non-specific protease. Either of such activities may be present in the S30 extract.

Table 2 Collagenase Digestion of the *in vitro* Synthesised Protein

Sample	Digestion conditions	TCA-insoluble (c.p.m.)	% protein solubilised
³ H-tryptophan-labelled whole chick extract*	– Collagenase	7,892	<1
	+ Collagenase	7,935	<1
³ H-proline-labelled collagen†	– Collagenase	11,205	<1
	+ Collagenase	450	96
<i>In vitro</i> synthesised protein	– Collagenase	8,830	0
	+ Collagenase	4,027	55

A large reaction (0.2 ml) was prepared and incubated as described in Table 1. Cold proline was added and the sample was incubated for another 20 min. Three aliquots were transferred to glass test tubes for collagenase assay and one aliquot was TCA-precipitated as described in Table 1. Calcium chloride, *p*-ethylmalamide and collagenase³¹ were added to the first sample, only CaCl₂ and *n*-ethylmalamide to the second, and no addition was made to the third. The tubes were all incubated in a shaking water bath at 37° C for 20 min. These samples were then precipitated with TCA-tannic acid.

* 5 μ Ci of neutralised ³H-tryptophan were layered on the allantoic membrane of 8-d chick embryos. The chicks were killed after 2.5 h of incubation, the heads were removed and the body doused in phosphate buffered saline. The homogenate was centrifuged at 17,500g for 30 min and stored at –20° C.

† ³H-proline labelled collagen was a gift from Dr David Rowe.

From the data presented here, we conclude that we have identified mRNA activities from embryonic chick calvaria which direct the synthesis of the $\alpha 1$ and the $\alpha 2$ chains of collagen. The mRNAs are functional in an heterologous cell-free system derived from Krebs II ascites cells. The cell-free synthesising system is totally dependent on the addition of mRNA and can be manipulated to be also tRNA dependent. The collagen mRNA is now being characterised, and the role of tRNA in its translational control is being pursued.

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Production by Stimulated Macrophages of Factors depressing Lymphocyte Transformation

MACROPHAGES can inhibit the responses of lymphocytes to a variety of stimuli. The presence of excessive numbers of normal macrophages led to inhibition of antibody formation by cultured mouse lymphoid cells¹⁻³. Normal rat spleen cell suspensions responded better to non-specific stimulation by Gram-negative bacterial lipopolysaccharide (endotoxin) after being freed of macrophages, but the response was reduced again by the addition of macrophages⁴. Spleen cells from mice injected with *Corynebacterium parvum*^{5,6} or subjected to a graft-versus-host (GvH) reaction^{6,7} showed decreased antibody formation⁷ and decreased responsiveness to phytohaemagglutinin (PHA) or allogeneic lymphocytes⁵ when cultured *in vitro*. Such mice possess activated macrophages^{8,9}. Their spleen cell responses were restored, at least in part, by removal of macrophages^{6,7}. Attempts to demonstrate the production of soluble inhibitors by macrophages *in vitro* have generally been unsuccessful^{6,7,10}. Mouse serum can inhibit primary antibody formation¹¹⁻¹⁴ and mitogen-induced transformation of T lymphocytes and B lymphocytes in cultures of mouse spleen cells; we have suggested (ref. 15; D. S. N. and C. N. Shneider, unpublished) that the factor responsible for the latter effect may be produced by macrophages. Here I present evidence that mouse peritoneal macrophages activated *in vivo* produce a potent inhibitor of lymphocyte transformation when cultured *in vitro*.

The mice used were A/J females, CBA/J males and (C57Bl/6J × A/J)_F₁(B6AF₁) females. Spleen cells were cultured in triplicate in small flat-bottomed vials as described elsewhere (ref. 15; D. S. N. and C. N. Shneider, unpub-

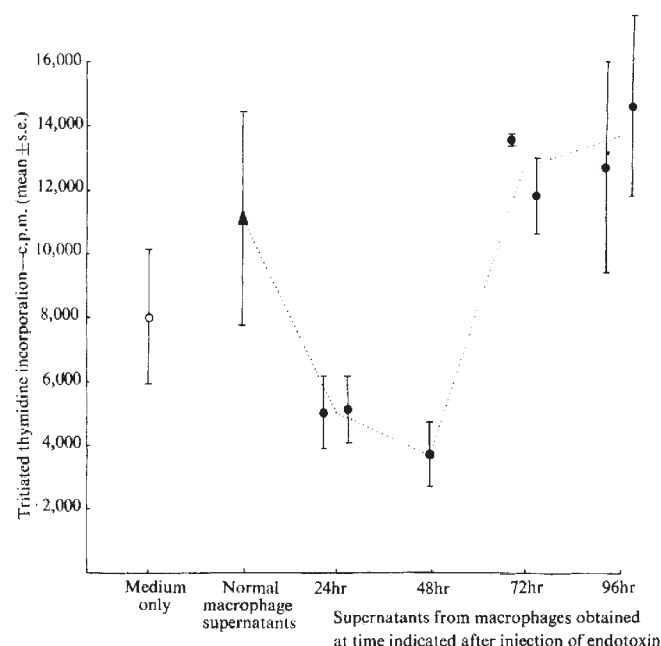


Fig. 1 Effect of supernatants from macrophages of endotoxin-treated CBA/J mice on PHA-induced DNA synthesis by normal CBA/J spleen cells. Donors received 400 µg of *Salmonella typhimurium* endotoxin s.c. at the times shown before collection; this treatment had previously been shown⁹ to produce marked activation. Each point represents the mean of triplicate tests of a single supernatant, except that for normal macrophage supernatants of which five were separate samples each tested in triplicate; the mean value for all five tests is shown. Vertical bars indicate standard errors. The differences between the effects of normal supernatants and those from mice injected 24 or 48 h previously with endotoxin are statistically significant ($P \leq 0.05$).

lished). To 0.6 ml of a suspension containing 7.5×10^6 viable normal spleen cells per ml of medium RPMI 1640 was added 0.4 ml of either RPMI 1640 containing 6.25% heat-inactivated normal human serum ("medium") or the supernatant from macrophages cultured in the same medium. Macrophages were obtained by washing out the peritoneal cavities of mice with 2 ml of Hanks' solution containing heparin (10 U ml^{-1}). Pooled peritoneal washings from three mice ($5-10 \times 10^6$ macrophages) were cultured for 3 h in 35 mm Falcon plastic Petri dishes, in an atmosphere of 5% CO_2 in O_2 . The dishes were thoroughly washed with a total of 20 ml RPMI 1640 to remove non-adherent cells. Three ml of the medium was added and the dishes were incubated for 24 h. The supernatants were removed, centrifuged at 750g for 10 min and added to spleen cell cultures either immediately or after storage at -20°C . The mitogens used were: phytohaemagglutinin P (PHA; Difco), Concanavalin A (con A; Calbiochem) and the lipopolysaccharide B (endotoxin) of *Escherichia coli* 055:B5 (Difco). Mixed lymphocyte reactions (MLRs) were induced by mixing 0.3 ml each of A/J and CBA/J spleen cells. Cells were cultured for 48 h or, in the case of MLRs, 96 h. Two µCi of tritiated thymidine (TRA-120, The Radiochemical Centre, Amersham) was added for the last 24 h; the cultures were processed for liquid scintillation counting as described elsewhere¹⁶.

Injection of endotoxins into mice causes morphological and functional activation of macrophages⁸. Figure 1 shows the effect, on PHA-induced transformation of normal CBA/J spleen cells, of culture supernatants from macrophages of CBA/J mice injected with *Salmonella typhimurium* endotoxin. When the mice had been injected 24 h or 48 h before collection of the macrophages the supernatants were markedly inhibitory. Supernatants obtained later were not inhibitory. Supernatants from normal CBA/J macrophages produced a slight but statistically insignificant increase in tritiated thymidine incorporation.

Table 1 Effect of Macrophage Culture Supernatants on PHA-induced DNA Synthesis by Normal A/J Spleen Cells

Material added to cultures	Tritiated thymidine incorporation (mean c.p.m. per culture ± s.e.) in cultures containing:	
	3.1 µg PHA	No PHA
Medium only	17,927 ± 2,880	1,440 ± 88
Supernatant from macrophages of normal mice	13,771 ± 488	2,414 ± 323
Supernatants from macrophages of mice injected 48 h previously with endotoxin from:		
<i>E. coli</i> 055 : B5 (W), 50 µg	7,601 ± 1,302	1,777 ± 144
<i>E. coli</i> 055 : B5 (W), 200 µg	1,718 ± 496	564 ± 78
<i>E. coli</i> 055 : B5 (B), 400 µg	2,621 ± 961	788 ± 110
<i>S. enteritidis</i> (B), 400 µg	2,049 ± 305	446 ± 51
<i>S. typhimurium</i> (B), 400 µg	2,785 ± 394	771 ± 90

Table 2 Effect of Macrophage Culture Supernatants on DNA Synthesis by Normal Spleen Cell Cultures in Response to Different Stimuli

Mouse strain	Stimulus	Tritiated thymidine incorporation in the presence of supernatants of cultures of macrophages from endotoxin-treated mice (% of controls)*
CBA/J	Nil	74
	PHA, 3.1 µg	27
	Con A, 1.2 µg	44
	<i>E. coli</i> endotoxin, 12.5 µg	40
A/J	Nil	49
	CBA/J spleen cells	26

* Macrophage donors injected subcutaneously with 400 µg *S. typhimurium* endotoxin, 48 h previously. Control cultures received medium only instead of macrophage supernatants.

Table 3 Effects of Serum and of Culture Supernatants from Macrophages of Mice with Graft-versus-Host Reactions on PHA-induced DNA Synthesis by Normal B6AF₁ Spleen Cells

Experiment	Material added to cultures	Source of material	Number of samples tested	Tritiated thymidine incorporation (mean c.p.m. per culture $\pm$ s.e.) in the presence of 3.1 μ g PHA
1	Medium only	—	1 (triplicate)	34,940 $\pm$ 2,809
	Medium plus 5% mouse serum	Normal mice	1 (pool from 12 mice tested in triplicate)	4,099 $\pm$ 461 †
	Medium plus 5% mouse serum	Syngeneic controls *	1 (pool from 12 mice tested in triplicate)	4,756 $\pm$ 655 †
	Medium plus 5% mouse serum	Mice with GvHR ‡	1 (pool from 12 mice tested in triplicate)	1,605 $\pm$ 42 §
2	Macrophage supernatants	Normal mice	6 (each tested in triplicate)	25,160 $\pm$ 3,323
	Macrophage supernatants	Mice with GvHR	5 (each tested in triplicate)	12,803 $\pm$ 2,250

* B6AF₁ mice injected with 5×10^7 B6AF₁ spleen cells 11 d earlier.

† B6AF₁ mice injected with 5×10^7 A/J spleen cells 11 d earlier.

‡ Significantly different from controls containing medium only ($P < 0.01$).

§ Significantly different from syngeneic or normal controls ($P < 0.01$).

|| Significantly different from cultures containing normal mouse macrophage supernatants ($P < 0.01$).

Table 1 shows the results of an experiment in which supernatants were obtained from macrophages of normal A/J mice, or mice injected 48 h previously with different endotoxins, and added to normal A/J spleen cells, with or without PHA. Supernatants from normal macrophages produced a statistically insignificant depression of PHA-induced DNA synthesis and a significant ($P=0.05$) increase in DNA synthesis in unstimulated cultures. Pronounced and significant ($P \leq 0.01$ in all cases) depression of PHA-induced DNA synthesis was caused by all the supernatants from endotoxin-treated mice; they caused less pronounced depression in unstimulated cultures. In other experiments supernatants taken from 48 h cultures of macrophages (the medium having been changed at 24 h) were much less depressive.

Table 2 summarises the results of two experiments to determine the effect of macrophage supernatants on the responses of normal spleen cells to different mitogens. Supernatants from macrophages of endotoxin-treated mice depressed the responses to all the T-lymphocyte mitogens (PHA, Con A and allogeneic spleen cells in MLRs) and to a B-lymphocyte mitogen (*E. coli* endotoxin).

Mice with GvH reaction were also used to see whether a totally different type of stimulus would increase the depressive activity of mouse serum and induce the production of an inhibitor by macrophages. B6AF₁ mice injected intravenously with 5×10^7 A/J spleen cells were found to undergo a non-fatal GvH reaction, with peak splenomegaly at 10–12 d. In separate experiments, serum and peritoneal macrophages were obtained after 11 d; serum and macrophage supernatants were tested for their effect on PHA-induced transformation of normal B6AF₁ spleen cells. Table 3 shows that, as in other experiments¹⁵, normal serum depressed DNA synthesis. Serum from control mice injected with syngeneic cells was equally depressive, but serum from mice with GvH reaction was markedly and significantly more depressive. Supernatants from macrophages of mice with GvH reaction, compared with control supernatants, also depressed DNA synthesis.

Some implications of these findings may be noted briefly. The production or release by stimulated macrophages of a potent inhibitor of lymphocyte transformation offers an explanation for the inhibitory effect of GvH reaction and *C. parvum* injections on the responses of mouse lymphoid cells to antigens or mitogens^{6,7}. Technical differences may account for the apparent lack of success of other workers^{6,7,10} in demonstrating the existence of soluble inhibitors. It is possible that macrophage-produced factors of this type could play a part in "sequential" antigenic competition, as suggested by Taussig¹⁷, and in the transient but marked depression of antibody formation following endotoxin injections¹⁸. The relationship between macrophage-produced factors and the inhibitor in mouse serum remains to be elucidated, but these findings strengthen the hypothesis¹⁵

that macrophages may be the source of this factor and possibly of the immunoregulatory α -globulin¹⁹ or normal immunosuppressive protein²⁰ found in fractions of normal human plasma, and the depressive factors found in serum from patients with a variety of diseases^{16,21}. Macrophages have now been implicated as a source of soluble factors with a variety of non-specific effects on lymphocyte function including reconstitution of the response of purified lymphocytes in MLRs²²; reconstitution of primary antibody formation by purified lymphocytes²³; potentiation of the response of thymocytes to PHA²⁴; and depression of lymphocyte transformation, as described here. The relationships among the factors responsible remain to be elucidated.

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Sex Ratio in Progeny of Mice Inseminated with Sperm treated with H-Y Antiserum

SPECULATION that immunological means could be used to control the sex ratio in mammals began when Eichwald and Siltser¹ provided evidence for a Y-linked histocompatibility antigen. Feldman² and Sachs and Heller³ initially suggested that serum from inbred females immunised by skin from males of the same strain (and assumed to contain antibody specifically directed against the Y antigen) might selectively impair the fertilising ability of sperm containing the Y chromosome. Testing of this hypothesis was hampered by lack of adequate systems for demonstrating and assaying H-Y antibody in the sera of immunised females. Consequently experiments designed to examine the possibility of immunoselection of gametes have until now all been carried out *in vivo*, and have involved determining the sex ratio of progeny from female mice that had rejected skin grafts from males of the same strain⁴⁻⁶.

The results of such experiments have been negative or equivocal, but it is not possible to decide whether this is because there is no basis for immunoselection (that is, no preponderance of H-Y antigen on Y-bearing sperm) or because sperm in the female reproductive tract are inaccessible to immunological attack.

We have devised methods for assaying H-Y antibody by the complement-dependent cytotoxicity test on sperm⁷ or on male epidermal cells in suspension⁸. This prompted us to test the effects of artificially inseminating mice with sperm that had been exposed *in vitro* to H-Y antibody of known cytotoxic potency, in the presence of complement. Thus we can re-examine the question of whether there is any expression of genes in post-meiotic cells, which might render Y-bearing sperm more susceptible than X-bearing sperm to cytotoxic H-Y antibody. The data we report here indicate that some degree of immunoselection against Y-bearing sperm is possible.

H-Y antiserum was prepared by grafting C57Bl/6 (B6) females two to eight times with skin from males of the same strain⁷. Serum was collected 6, 8, and 10 d after the second and subsequent skin grafts, and the three bleedings after each graft, from individual females, were pooled and tested for cytotoxic activity on sperm. Sera were used in experiments only when they fulfilled the criterion of killing 20–30% of sperm above controls at a dilution of 1/8 using horse complement⁹. Ninety separately prepared samples of H-Y antiserum were used in this study. For each female to be artificially inseminated pooled epididymal and vas deferens sperm from (B6×A)_F₁ males were mixed with antiserum and complement in these quantities: 5×10⁶ sperm suspended in 0.05 ml undiluted H-Y antiserum plus 0.05 ml absorbed horse serum (complement source) diluted 1/20 in M-199 and incubated 35–45 min at 37° C. About 70–80% of all sperm can be expected to be dead under these conditions; we did not do viability counts on each preparation. The number of sperm used was empirically determined to be the minimum necessary to achieve a satisfactory incidence of fertilisation (5–10% of inseminations resulted in pregnancy); the amount of antibody was limited to 0.05 ml because vaginal instillation of a total volume of more than 0.1 ml is impracticable. The conditions used thus gave the highest feasible antibody:sperm ratios. Recipient females came from random-bred stock, and were inseminated with a 1 ml syringe 24–30 h post-partum, at which time they could be expected to have ovulated¹⁰; post-partum females were chosen because we thought the relaxed condition of their genital tract might favour the retention of the instilled sperm suspension.

Two sets of control data were collected throughout the period occupied by this study. Natural litters born to

random-bred females mated to (B6×A)_F₁ males indicate the normal sex ratio from such males. Second, litters produced by artificial insemination of B6 females with (B6×A)_F₁ sperm treated with anti-H-2^a or anti-H-2^b serum, according to the schedule above, served to control for whether the procedure of artificial insemination itself, or exposure to any mouse antiserum, might adversely affect Y-bearing as compared with X-bearing sperm. [These latter controls incidentally serve as a preliminary test of whether H-2 antigens exhibit "haploid expression", as has been reported for H-LA antigens on human sperm¹⁴—but no evidence for haploid expression of H-2 was found, fourteen out of twenty-seven offspring from sperm treated with anti-H-2^a being H-2^a/H-2^b heterozygotes, as were ten out of eighteen offspring from sperm treated with anti-H-2^b.]

Table 1 presents the control data from natural litters at sequential monthly intervals (each of which yields a sample size roughly equivalent to the total progeny obtained from artificial insemination) together with χ^2 and *P* values indicating the deviation of each sample from the overall sex ratio of 53.3% males. No significant departures were found; the individual samples are remarkably free of random variation or seasonal fluctuation.

Table 2 indicates a sex ratio of 45.4% males for progeny of females inseminated with anti-H-Y-treated sperm as compared with 53.4% for natural births and control artificial inseminations combined ($\chi^2=9.7$; *P*<0.003). These results indicate that Y-bearing sperm can be selectively impaired by anti-H-Y antibody; the implication is that sperm containing the Y-chromosome have more H-Y antigen on their surface than do X-bearing sperm, and this in turn implies post-segregational activity of the gene or genes responsible for H-Y antigen. Evidence for low levels of RNA synthesis during spermatid stages in the mouse is given by Monesi¹² and by G. B. Doohar (personal communication).

The simplest interpretation of our data might be that the percentage deviation of the sex ratio observed is a true measure of the average quantitative variance of H-Y antigen between X-bearing and Y-bearing sperm. The relatively minor shift in sex ratio after treatment of sperm with H-Y antibody would on these grounds indicate only relatively small quantitative differences in H-Y between the two types of sperm, implying that much of the sperm membrane is conserved from the diploid state. Immunoelectron microscopy indicates, however, that the representation of H-Y on mouse sperm, in a single sample, ranges from little or none to a certain maximum, with many sperm falling at the two extremes¹³. This may imply that haploid expression is more extensive than the results of this study suggest.

We suspect the immunoselection method we use to be deficient in at least two respects. First, treatment of nucleated cells by antibody and complement in operationally "weak" systems like H-Y invariably leaves many antigen-positive cells viable. Second, H-Y antisera produced by skin

Table 1 Sex Ratios in Monthly Subsamples of Progeny of (B6×A)_F₁ Male Mice

♂	♀	Total	%♂	χ^2	<i>P</i>
146	124	270	54.1	0.06	>0.5
184	153	337	54.6	0.19	>0.5
221	183	404	54.7	0.25	>0.5
343	280	623	55.1	0.64	>0.5
240	215	455	52.7	0.08	>0.5
373	326	699	53.4	0.00	>0.5
272	238	510	53.3	0.00	>0.5
381	329	710	53.7	0.02	>0.5
246	204	450	54.7	0.32	>0.5
235	232	467	50.3	1.68	>0.2
182	185	367	49.6	2.14	>0.1
106	104	210	50.5	0.69	>0.5
196	161	357	54.9	0.28	>0.5
			53.3		

Table 2 Effect of Anti-H-Y Treatment of Sperm on Sex Ratio of Progeny Obtained by Artificial Insemination

a	Controls	♂	♀	% ♂
Litters after natural matings		3,125	2,734	5,859 53.3
Litters after anti-H-2 treatment of sperm and artificial insemination		57	41	98 58.2
Totals		3,182	2,775	5,957 53.4
$\chi^2=1.0 \quad P>0.3$				
b	Experimental litters after anti-H-Y treatment of sperm and artificial insemination	♂	♀	% ♂
		169	203	372 45.4
$\chi^2=9.7 \quad P<0.003$				

grafting are commonly contaminated with non-H-Y antibody that is cytotoxic for sperm. This was fully appreciated only when Koo¹³, studying H-Y antigen on mouse sperm by immuno-electron microscopy, established that epidermal cells and sperm share an autoantigen to which an immune response is provoked by skin grafting¹³. This antibody must to an unknown degree have produced indiscriminate cytolysis of sperm in our experiments, thus lowering the sensitivity of the method.

Satisfactory approaches to remedying both these deficiencies are known, and we are studying them. In the meantime, there is a strong possibility that a more pronounced deviation of the sex ratio than we have yet achieved is attainable in the mouse.

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elements where they produce substances causing disease symptoms. The identity of these substances is still controversial. Both fungi, however, readily produce *in vitro* enzymes that degrade various polysaccharide components of plant cell walls and there is evidence that one or more of these enzymes may be implicated in the wilt syndrome. Information already available on enzyme synthesis is contradictory, and so information on factors controlling synthesis of these enzymes may, therefore, contribute to understanding of pathogenesis in vascular wilts.

As some of the past work on synthesis was based on methods now known to be unsatisfactory in certain respects, we have re-investigated the problem with techniques that avoid difficulties inherent in much of the earlier work. These difficulties are overcome by limiting the availability of the substrate in a continuous-feeding culture, thus reversing the effects of catabolite repression operative in batch culture containing excess substrate. This approach has been effectively used by other workers to reveal the true nature of inducibility of polysaccharide-degrading enzymes¹⁻⁸. We describe here a more rapid and highly reproducible technique applicable to shake-flask cultures.

The fungi were grown on a medium containing inorganic salts (N as NaNO₃) and the following carbon sources: various sugars and uronides found as constituents of plant cell wall polymers; polymers containing linkages found in herbaceous cell walls including sodium polypectate, pectin, carboxymethyl cellulose, xylan, arabinan and cell walls prepared from stems and petioles of 7-week-old tomato plants, grown at 25° C, by the method of Karr *et al.*⁴.

Standardised inocula of fungal spores were obtained by transferring 1 ml of a sucrose (1.5%)/salts culture of *V. albo-atrum*, or sucrose (1.5%)/casamino acids culture of *F. oxysporum* grown for 3 d on a rotary shaker (150 r.p.m.) at 25° C into 50 ml glucose (0.5%)/salts shake culture; after 40 h cells, mainly as conidia and bud cells, were collected by centrifugation and suspended in 100 ml inorganic salts medium contained in 250 ml Erlenmeyer flasks at 150 r.p.m. Little or no glucose was carried over with the cells.

Various carbon sources were supplied to shake cultures from diffusion capsules⁵ from which they passed into the ambient liquid at low linear rates determined by their concentration and number of membranes through which they diffused (restricted cultures). Capsules were replaced before sugar release became non-linear. For most purposes 100 ml cultures were supplied at the rate of 2–4 mg sugar h⁻¹. For comparison carbon sources were added directly to the medium at initial concentrations of 1% (w/v) (unrestricted cultures); insoluble compounds were added as finely divided powders.

At intervals after inoculation shake cultures were assayed for growth and, after dialysis, for one of a number of enzyme activities on the polymers listed above and galactan (from the lupin), and also for β -D-galactosidase, β -D-mannosidase, β -D-glucosidase, β -D-glucuronidase and α -L-fucosidase activities against their respective *p*-nitrophenol derivatives. Enzyme activities were measured as release of reducing sugars⁶ (arabinanase, xylanase and galactanase), saturated and unsaturated galacturonides by a modified thiobarbituric acid test⁷, endo-polygalacturonase (endo-PG) and endo-pectin trans-eliminase (endo-PTE), *p*-nitrophenol (aryl glycosidases), and by viscometric assay (endo-PG and cellulase (Cx)). All activities are corrected for fungal growth by expressing enzyme units per 4×10^9 spores ml⁻¹.

In cultures of *V. albo-atrum* on cell walls, a number of cell wall degrading enzymes were produced sequentially during the growth period of 2–9 d. Endo-PG was synthesised after 2 d followed by arabinanase and endo-PTE. Xylanase and cellulase (Cx) activities were detectable at very low levels before 6 d after which production was rapid. β -D-Galactosidase activity and low levels of β -D-glucosidase activity were also detected. Sequential polysaccharide synthesis has been reported for other plant pathogenic fungi grown on host

Induction of Synthesis of Extracellular Cell-wall Degrading Enzymes in Vascular Wilt Fungi

THE vascular wilt fungi *Verticillium albo-atrum* and *Fusarium oxysporum* f. sp. *lycopersici*, pathogenic to tomato plants, are characteristically confined to the vascular

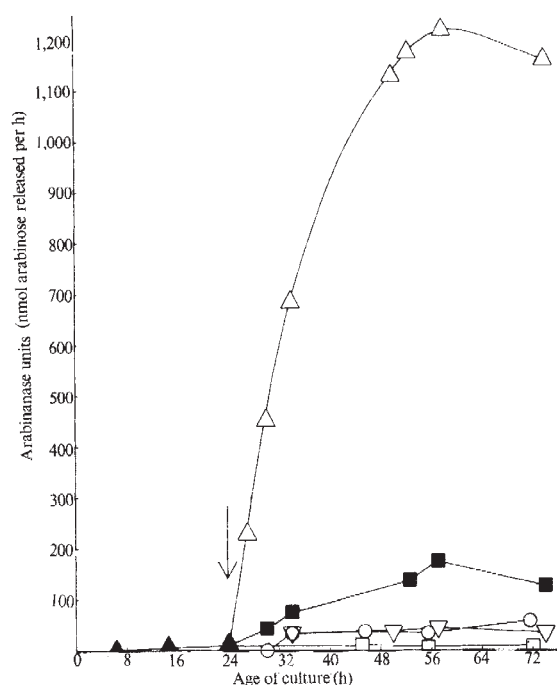


Fig. 1 Induced and constitutive synthesis of arabinanase by *V. albo-atrum*. Sugars were supplied in excess in unrestricted (U) cultures or at 2–4 mg per 100 ml per h in restricted (R) cultures. ▲—▲, Glucose (R); △—△, arabinose (R); ○—○, arabinose (U); ▽—▽, xylose (R); □—□, xylose (U); ■—■, galactose (R). Other cell-wall sugars allowed constitutive synthesis of the same order or below that of xylose (R) and have been omitted for the sake of clarity. The arrow depicts the time when diffusion capsules containing sugars to be screened for their ability to induce enzyme synthesis replaced capsules from the 24 h glucose pretreatment.

plant cell walls⁹; in each case a similar sequence was observed. There were no significant differences in enzyme activities of filtrates from *V. albo-atrum* cultures on cell walls from resistant and susceptible host plants. Specific activities were generally much higher than in cultures grown on solutions of particular polymers. *F. oxysporum* cultures were not analysed in the same detail, but after 11 d high activities of a similar range of polysaccharidases to those produced by *V. albo-atrum* were detected.

Unrestricted cultures gave results that were difficult to interpret in terms of induction and repression of enzyme synthesis as, indeed, is much of the published work. Polysaccharidase activities were generally absent or very low in these conditions. More easily interpreted results were obtained from restricted cultures in which the concentrations of sugar monomers in the culture fluid remained between 0 and 0.001% (w/v) during growth of the pathogen. In these conditions the growth rates of *V. albo-atrum* and *F. oxysporum* (measured as spore number h⁻¹) were respectively 1/11–1/30 and 1/8.5 of those in unrestricted culture.

If enzyme synthesis is constitutive and controlled by catabolite repression, then one or more of the enzymes mentioned above should accumulate in cultures with a restricted supply of glucose^{1,2}. In cultures grown for 48 h at pH 3.5, 5.5 and 7.5, however, activities of each enzyme were either absent or barely detectable.

In further experiments in which various monomeric sugars were tested as inducers of enzyme synthesis, cultures of the pathogens were pretreated with restricted glucose-feeding for 24 h to decrease the steady-state concentration of intracellular metabolic intermediates, because the response of microorganisms in a repressed state to the presence of inducers is less rapid. Capsules containing glucose were then replaced with others containing various sugars. Periodic assays of dialysed culture filtrates showed that almost always

enzyme synthesis was specifically induced as follows: endo-PG and endo-PTE by D-galacturonic acid, arabinanase by L-arabinose, xylanase by D-xylose, galactanase and β-galactosidase by D-galactose, and cellulase (Cx) by cellobiose. A characteristic pattern of induced and constitutive enzyme synthesis is given by arabinanase (Fig. 1).

An interesting anomaly was that for synthesis of galactanase and β-galactosidase, L-arabinose was a much more effective inducer than D-galactose. This enhanced synthesis was approximately four times greater for *F. oxysporum* β-galactosidase and seven to ten times greater for *V. albo-atrum* β-galactosidase production on restricted arabinose compared with restricted galactose cultures. In the early stages of induction, however, the maximum rate of synthesis was achieved by *V. albo-atrum* on arabinose after only 2.5 h; at this stage enzyme activity was sixty-fold greater than in comparable galactose cultures. A similar degree of cross-induction by galactose on arabinanase synthesis also occurs. The highly specific induction of synthesis of other enzymes by both pathogens was also very rapid. Thus, for *V. albo-atrum* after 3 h, xylanase and arabinanase activity had reached one third and one fifth respectively of the maximum specific activities detected after 36 h growth. No α-D-mannosidase, α-L-fucosidase, β-D-glucuronidase or β-D-xylosidase activities were detected in any culture conditions.

The degree of specificity of induction of synthesis by *V. albo-atrum* is shown in Table 1. Similar results were obtained for *F. oxysporum*. Specificity was virtually complete for endo-PG, endo-PTE and cellulase (Cx). It was high for the other enzymes and probably higher than indicated because of the difficulty in distinguishing between constitutive synthesis and apparent constitutive synthesis arising from the action of enzymes on a heterogeneous substrate such as arabinan containing some galacturonic acid. Thus, the arabinanase apparently synthesised in response to galacturonic acid may reflect the activity of endo-PG or endo-PTE on regions of the arabinan polymer containing galacturonic acid. Where the substrate is pure or the enzyme assay is definitive, however, induction of synthesis is highly specific.

The above results suggested that even in conditions of induction by particular sugars, synthesis could be affected by catabolite repression if the concentration of the monomer in culture became excessive. Accordingly, *V. albo-atrum* was supplied with various monomeric sugars at different rates, and cultures were assayed for enzyme activity per unit of fungal growth. Synthesis of endo-PG and endo-PTE increased almost linearly when supplied with galacturonic acid

Table 1 Induction of Synthesis of Polysaccharidases of *Verticillium albo-atrum* by a Restricted Supply of Cell-wall Sugars

Inducer †	Enzyme activities *					
	Endo-PG	Endo-PTE	Arabinanase	β-Galactosidase	Xylanase	Cellulase (Cx)
D-Galacturonic acid	100	100	15.8	0	16.5	0.30
L-Arabinose	0	0	100	100	3.5	0.25
D-Galactose	0	0	14.4	12.9	5.2	0.37
D-Xylose	0	0	3.7	0.26	100	0.08
D-Glucose	0–1.25	0	0–5.8	0.34	5.8	1.46
D-Mannose	0	0	0	0.34	0	0.20
L-Rhamnose	2.10	9.11	6.6	0	0	0.40
L-Fucose	1.38	0.16	0	0	0	0.25
Cellobiose	3.7	1.34	—	0	—	100
D-Glucuronic ‡ acid	—	—	—	—	—	—

* Enzyme activities are expressed as a percentage of the maximum specific activities attained in culture after identical periods of exposure to different sugars.

† Sugars were fed from diffusion capsules at linear rates of 2–4 mg per 100 ml per h to shake cultures of *V. albo-atrum* containing initially 4×10^9 spores ml⁻¹.

‡ D-Glucuronic acid is not utilised by this strain of *V. albo-atrum*.

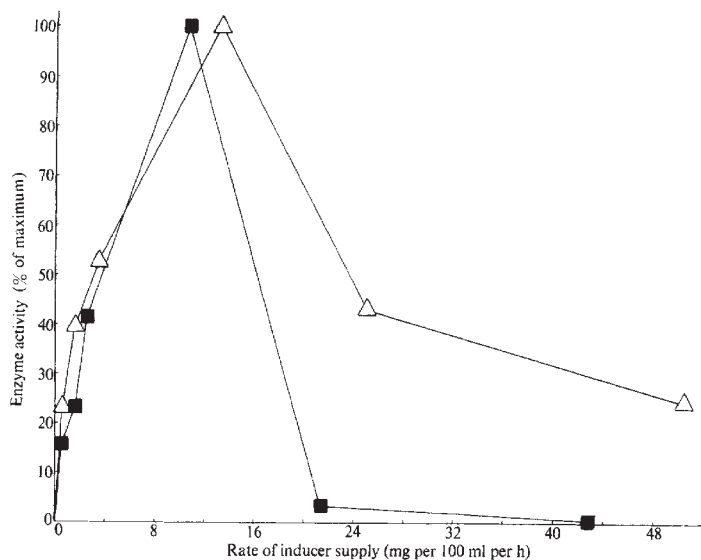


Fig. 2 Synthesis of endo-PG (■—■) and arabinanase (△—△) by *V. albo-atrum* in restricted cultures supplied with increasing rates of galacturonic acid and arabinose respectively. Enzyme activities are expressed as percentages of the maximum specific activity attained 10 h after addition of inducer.

from 0 to about 10 mg per 100 ml per h but decreased rapidly at higher values, for example about 90% at 20 mg per 100 ml per h. At twice this rate, repression of synthesis was almost complete. Synthesis of arabinanase and B-galactosidase on arabinose followed a similar pattern up to the same optimum rate of inducer supply beyond which synthesis continued at the relatively high rates of 22–67% of the maximum even at rates of about 50 mg per 100 ml per h and greater (Fig. 2). Further analysis showed that when enzyme synthesis started to decrease, inducing sugars began to accumulate in the cultures.

These results emphasise the highly inductive nature of synthesis of a variety of enzymes that degrade polymers of plant cell walls, especially those acting on pectic substrates, and the extreme susceptibility of this synthesis to catabolite repression. The results for the pectic enzymes are of particular interest because of the evidence that implicates them in the wilt syndrome. Their synthesis is induced in a highly specific manner by galacturonic acid, constitutive synthesis is at very low rates and synthesis is very sensitive to catabolite repression. The induction of enzyme synthesis by pectic polymers probably depends on the release of galacturonic acid by constitutive enzyme; once the process is initiated it should become autocatalytic. *Prima facie*, conditions in vascular elements would seem to be suitable for the synthesis of these enzymes and in this connection we have isolated from stems of tomato plants infected with *V. albo-atrum* amounts of an endo-pectin *trans*-eliminase which are of the same order as those which when applied to healthy cuttings reproduce many of the natural symptoms of a vascular wilt.

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Ethylene as a Cause of Soil Fungistasis

Soil fungistasis is the term applied to the widespread inhibition of the germination of fungal propagules in soil under apparently favourable conditions unless supplied with exogenous nutrient¹. No satisfactory explanation has been given for this phenomenon although a number of hypotheses have been proposed².

Experiments in our laboratory with water-saturated airstreams passing over soil implicated a volatile factor as the cause of soil fungistasis. Volatile inhibitors are assuming increased importance as possible causes of fungistasis^{2,3} since Balis and Koureas⁴ suggested that a volatile unsaturated hydrocarbon may be involved. Volatile materials were identified by gas chromatography from about fifty soils collected throughout Australia with different origins and histories. Ethylene was the only material identified in all soils in concentrations likely to be biologically active. Ethylene has recently been identified in soil under anaerobic conditions⁵. In this study, ethylene was found to be produced in appreciable quantities in open, aerobic systems. Results with sterilised soil indicate that the ethylene is formed by microbial activity.

Soils to be tested for production of volatiles were dried for 24 h at 40° C and passed through a 0.1 cm mesh sieve; 30 g samples were packed into glass tubes (16 cm by 2.5 cm) and wetted to field capacity. Gas samples were withdrawn from a 3.5 ml sampling tube fitted into the base of each soil tube. Ethylene was identified by flame ionisation chromatography using a stainless steel column packed with Poropak N. Identification was confirmed against authentic samples of ethylene on 0.35 m and 2.0 m Poropak N columns and by the use of the mercuric perchlorate technique⁶.

Ethylene production and chemical properties of some of the soils studied are given in Fig. 1 and Table 1. There is a correlation between organic matter and total nitrogen content of soil and ability to produce ethylene.

Sclerotia of *Sclerotium rolfsii* Sacc. and spores of *Helminthosporium sativum* Pamm., King and Bakke were used in experiments to determine if a relationship exists between the ability of a soil to produce ethylene and its level of fungistasis. The soils cited in Table 1 were dried and sieved as described; 20 g samples were placed in Petri dishes of diameter 9 cm and wetted to field capacity. Filter paper wicks dipping in water maintained the soils at field capacity. With *S. rolfsii*, thirty mature sclerotia taken directly from potato dextrose agar (PDA) cultures were placed on the soil surface in each Petri dish. One Petri dish of each soil was left on the laboratory bench where air turbulence caused by air-conditioning units was measured to be 13–17 m min⁻¹ (non-aerated treatment). In a duplicate sample of each soil a water-saturated airstream (150 ml per min per dish) was passed through a hole in the centre of the Petri dish lid so that the air flowed over the surface of the soil and out at the edge of the lid. Germination of sclerotia in aerated and non-aerated treatments is shown in Fig. 2 and Table 2. Germination of spores of *H. sativum* was similarly tested, mature spores being collected from a spore suspension on filters of diameter 4.7 cm and pore size 0.22 µm: the filters were placed on the soil surface in the centre of each Petri dish, and germination of spores was recorded on aerated and non-aerated soil (Table 3).

These experiments confirm that there is a correlation between the ability of a soil to produce ethylene and its level

Table 1 Chemical Analyses of Soils

Soil	Origin	pH	Organic matter %	Total N %	PO ₄	Ca	Mg	Na	K
Kidd from avocado grove, South Queensland	Basalt	5.8	25.1	0.67	4.9	22.9	6.0	0.8	0.47
Mt Wilson from grassland, New South Wales	Basalt	5.6	13.1	0.36	0.7	6.8	1.6	0.9	0.21
Ashburner from avocado grove, South Queensland	Basalt	6.6	14.3	0.62	4.9	21.2	5.1	0.2	1.74
Duranbah from avocado grove, north New South Wales	Basalt	4.9	9.4	0.40	3.2	1.9	0.7	2.3	0.37
Mullumbimby from avocado grove, north New South Wales	Basalt	6.4	18.7	0.32	140.7	13.4	4.8	0.1	1.01
Gosnell from <i>Eucalyptus marginata</i> forest, Western Australia	Lateritic sand	5.2	4.8	0.02	0.7	0.8	0.2	0.1	0.04
Penrith from garden soil, New South Wales	Alluvial	5.8	3.8	0.18	164.6	8.6	2.2	0.4	1.18
Rydalmere from potting loam, New South Wales	Alluvial	5.8	6.4	0.11	4.3	5.7	2.2	0.3	0.39
Epping from garden soil, New South Wales	Shale	5.8	5.7	0.15	116.4	8.1	1.2	0.3	0.32

Table 2 Germination (%) of *Sclerotium rolfsii* Sclerotia on Non-aerated and Aerated Soil

Soil	Non-aerated		Aerated (150 ml min ⁻¹)	
	3 d	6 d	3 d	6 d
Kidd	0	17	20	73
Mt Wilson	7	20	17	43
Ashburner	3	23	13	60
Duranbah	7	23	23	47
Mullumbimby	17	30	17	53
Gosnell	0	23	53	77
Penrith	23	50	60	83
Rydalmere	7	40	20	83
Epping	13	43	47	67

of fungistasis. The few anomalies in the results are to be expected because of interaction of other factors such as differences in microbial competition and levels of nutrient in the soils. The results clearly show the nullifying effect of an airstream on fungistasis.

To establish that ethylene causes fungistasis, a series of glass tubes (16 cm by 1.3 cm) containing a layer of either Ashburner or Penrith soils (5 g dry soil per tube) were prepared, soil

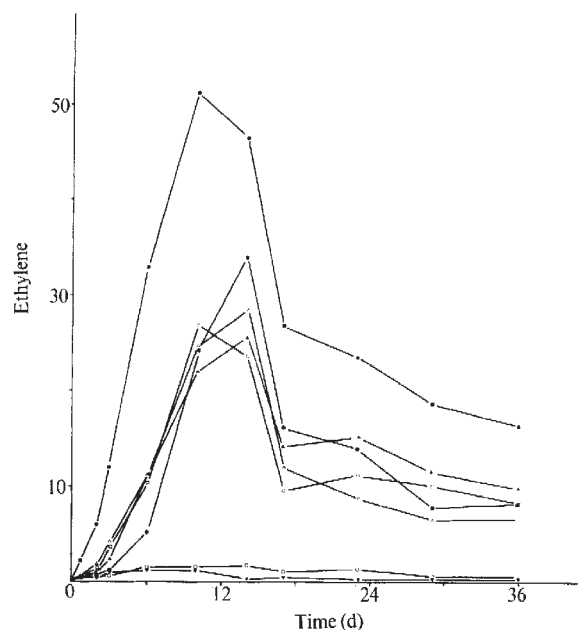


Fig. 1 Ethylene production by soil. Rydalmere and Epping soils produced ethylene at levels between those produced by Gosnell and Penrith soils but their curves are omitted from the graph to avoid confusion. Soils: ■, Kidd; ▲, Mt Wilson; □, Ashburner; ●, Duranbah; △, Mullumbimby; ○, Gosnell; ▼, Penrith.

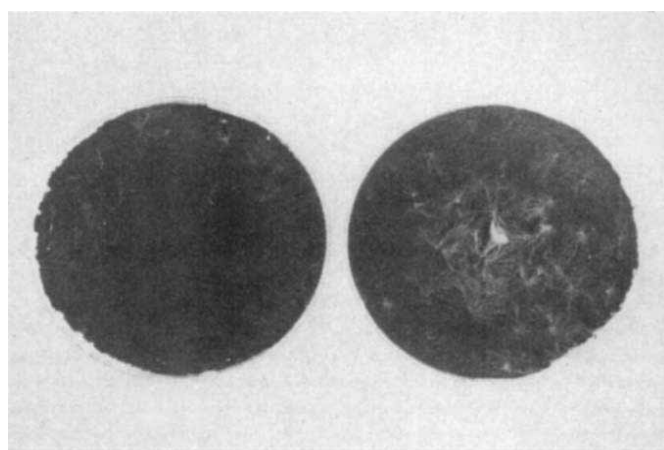


Fig. 2 Germination of sclerotia of *Sclerotium rolfsii* on Rydalmere soil. Left, non-aerated; right, aerated with airstream through hole in centre of Petri dish lid.

was wetted to field capacity, and sclerotia of *S. rolfsii* placed on the soil surface. Three treatments were used with each soil: a saturated airstream (500 ml min⁻¹) containing less than 0.01 volumes per million (v.p.m.) ethylene, a saturated airstream (500 ml min⁻¹) containing 1 v.p.m. ethylene passed over the soil, and a still atmosphere maintained in tubes by plugging their ends with cotton wool. Germination of sclerotia is shown in Table 4.

Moulds proliferated to form a dense mycelium on the soil surface in all tubes treated with an airstream without ethylene. No mould growth was visible in other treatments. Fungi isolated from the mycelia on the soil surface included species of *Pythium*, *Fusarium*, *Trichoderma*, *Penicillium*, *Aspergillus*, *Cephalosporium*-like fungus, and many unidentified fungi. Germination of the test fungus was relatively poor in the presence of vigorous mould growth and this may result from

Table 3 Germination* (%) of *Helminthosporium sativum* Spores† on Non-aerated and Aerated Soil

Soil	Non-aerated	Aerated (150 ml min ⁻¹)
Kidd	4	61
Mt Wilson	9	63
Ashburner	4	51
Duranbah	7	52
Mullumbimby	5	36
Gosnell	13	67
Penrith	19	65
Rydalmere	8	67
Epping	7	60

* After 3 d.

† At least 400 spores counted per treatment.

competition. At the end of the experiment, a water-saturated airstream without ethylene was passed over sclerotia inhibited from germination in both non-aerated and ethylene-treated tubes. Many sclerotia then germinated within a few days and moulds developed on the soil surface. Thus, at the levels tested, ethylene causes no permanent damage to sclerotia of *S. rolfsii* or to the mould propagules.

Table 4 Effect of Ethylene on Germination (%) of *Sclerotium rolfsii* Sclerotia on Soil

Soil	Aerated + v.p.m. C_2H_4 (500 ml min ⁻¹)	Aerated (500 ml min ⁻¹)	Non-aerated
Ashburner	0	35	0
Penrith	0	48	10*

* Only sclerotia nearest ends of tubes germinated.

Although all soils tested were fungistatic, they showed marked differences in ability to produce ethylene. Evidence from other experiments with addition of organic amendments to soil shows that there is an interaction between nutrient levels for microbial growth and the concentration of ethylene required to maintain fungistasis. Soils rich in nutrients produce more ethylene but such soils require higher levels of ethylene to inhibit germination of fungal propagules. Thus, following the terminology of Watson and Ford², nutrient is the main stimulator of propagule germination and ethylene the main inhibitor. The balance between the two determines whether a soil is fungistatic at any given time. This balance between stimulator and inhibitor would also explain why the addition of nutrients to soil temporarily annuls fungistasis¹.

Ethylene also affects other microorganisms including bacteria, actinomycetes and nematodes in soil and, therefore, will almost certainly have a marked influence on most soil processes including turnover of organic matter and mineralisation of nitrogen. The concept of a balance between nutrient, the stimulator, and ethylene, the inhibitor, has far-reaching implications for the study of the occurrence and control of soil-borne plant diseases, especially those caused by fungal pathogens.

Chemical analyses of soils were done by the Chemistry Branch, Biological and Chemical Research Institute, Rydalmere.

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¹ Dobbs, C. G., and Hinson, W. H., *Nature*, **172**, 197 (1953).

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Energetic Cost of Locomotion in Kangaroos

THE hopping of kangaroos is reminiscent of a bouncing ball or the action of a pogo stick. This suggests a significant storage and recovery of energy in elastic elements. One might surmise that the kangaroo's first hop would require a large amount

of energy whereas subsequent hops could rely extensively on elastic rebound. If this were the case, then the kangaroo's unusual saltatory mode of locomotion should be an energetically inexpensive way to move.

Recent studies on quadrupedal mammals have shown that the energetic cost of their locomotion varies in a regular manner with size, and the oxygen consumption of a running mammal can be predicted quite closely if its speed and weight are known¹. This relationship between weight and energetic cost of locomotion for quadrupedal animals provides a baseline against which the energy expended by the hopping kangaroo can be compared. In this study we set out to answer the simple question: Is it cheaper for an animal to hop or to run?

Two red kangaroos (*Megaleia rufa*, 18 and 28 kg average weight, both female) were trained to hop on a treadmill (236 cm long and 76 cm wide) while wearing a lightweight ventilated face mask. Steady state oxygen consumption was measured for 5 to 20 min while they travelled at speeds from 1.0 to 22 km h⁻¹. Air temperature was 24° C and wind speed was approximately matched to tread speed. Oxygen consumption increased to a nearly constant value after a minute of hopping at each speed and returned to the resting level almost immediately after the animal stopped. We assumed that the constant level reflected a steady state oxygen consumption and that there was no significant anaerobic metabolism since the oxygen debt observed after a run never amounted to more than 2% of the oxygen consumed during the run. Furthermore, it was clear that maximum levels of aerobic metabolism had not been reached during our experiments, for when the animal struggled we observed oxygen consumption values up to twice those observed at the highest speeds at which we were able to achieve sustained hopping. Oxygen consumption of the animal was measured by pulling room air through a mask at metered rates (300 to 340 l min⁻¹) and measuring the difference in oxygen concentration between air entering and leaving the mask (using a Beckman F-3 paramagnetic oxygen analyser). The error involved in this procedure was determined to be less than $\pm 2\%$ by bleeding nitrogen into the mask at known rates (simulating the extraction of oxygen by the animal). In separate experiments stride frequencies were counted at speeds from 1.0 to 25 km h⁻¹. Each reported observation is the mean of three half-minute counts. Stride length was calculated from stride frequency and treadmill speed.

At low speeds the kangaroo does not hop but moves by what can perhaps best be described as a 'pentapedal type' of locomotion, since the animal uses its heavy tail as a fifth leg. This type of locomotion has also been called 'slow progression'². When moving in this manner the animal (starting with its hind feet and tail on the ground): (a) puts its front feet on the ground and pulls its tail towards the body causing the hind limbs to lift until only the rear toes are touching; (b) swings its hind limbs forward together while supporting itself on its front limbs and tail; (c) lifts its front legs off the ground; and (d) moves its front feet forward as it repeats the cycle. This form of locomotion not only looks awkward but appears to be energetically quite costly compared to quadrupedal running (Fig. 1a). Oxygen consumption increased nearly linearly as the animal increased its speed from 1 to 6 km h⁻¹ while moving pentapedally (slope 0.66; y intercept 0.35; correlation coefficient 0.96 for the 18 kg animal). Oxygen consumption at 6 km h⁻¹ was about twenty times the predicted standard metabolic rate³. The observed slope for the relationship between oxygen consumption and pentapedal speed was 3.9 times that predicted for an 18 kg animal running on four legs. The increase in speed while moving pentapedally was achieved primarily by increasing stride frequency (Fig. 1b) and stride length increased only slightly (Fig. 1c).

The kangaroos changed from the 'pentapedal type' of locomotion to bipedal hopping between 6 and 7 km h⁻¹. As the animals increased their hopping speed (from 7 to 22 km h⁻¹ in the smaller kangaroo) there was a slight decline in oxygen consumption. This slight decline does not represent a maximum

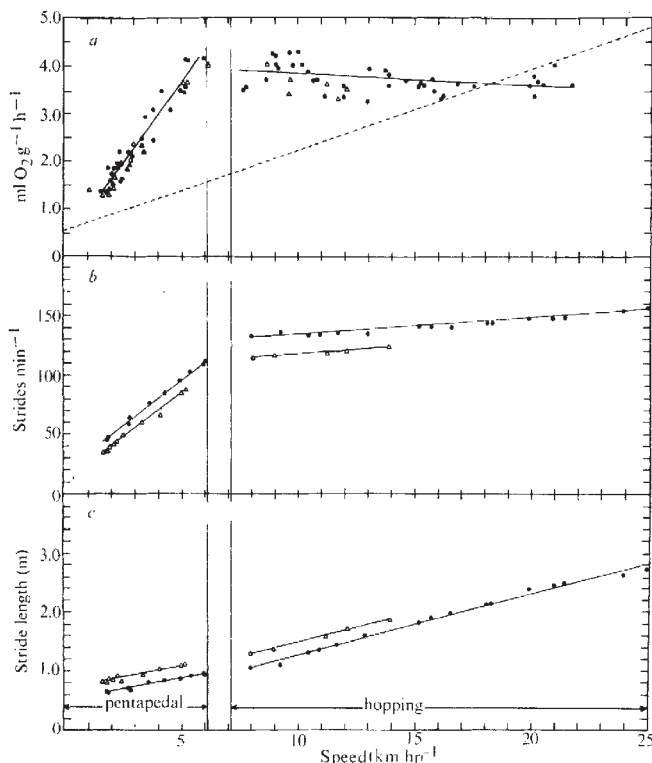


Fig. 1 *a*, Steady state oxygen consumption; *b*, stride frequency; *c*, stride length of the red kangaroo as a function of speed. The dashed line in *a* represents the oxygen consumption predicted for an 18 kg mammal running quadrupedally¹. Data are from two female animals which weighed 18 kg (●) and 28 kg (△). The regression lines for oxygen consumption as a function of speed were calculated (method of least squares) using only the data from the 18 kg animal. For pentapedal locomotion, $n=27$, slope=0.66, y intercept=0.35, correlation coefficient=+0.96 $P<0.001$. For hopping, $n=39$, slope=-0.026, y intercept=4.09, correlation coefficient=-0.40 $P<0.01$. Stride frequency was measured separately from oxygen consumption, thus the data points in *b* and *c* do not correspond with those in *a*. The lines for stride frequency and stride length as a function of speed were fitted by eye.

sustained oxygen consumption since the animals were capable of more than doubling their metabolism above this level when they struggled. The values for oxygen consumption of the 28 kg kangaroo tended to be lower than those from the 18 kg animal (Fig. 1*a*). We were, however, unable to obtain higher speeds safely with the larger animal because our treadmill was too short.

The number of hops min^{-1} , like the oxygen consumption, was nearly the same over a wide range of speeds (Fig. 1*b*), thus the animals increased their speed primarily by increasing the distance per hop (Fig. 1*c*). The almost constant hopping frequency observed over a three-fold change in speed means that the duration of each hop is constant. The time on the ground, however, decreases and time off the ground increases. The 18 kg kangaroo with its shorter legs hopped at a higher frequency than the 28 kg animal.

Although the distance per hop increased with increasing speed, the amount of energy expended per hop was nearly constant. Thus the animals achieved greater acceleration on take-off as they moved faster, without expending more energy. This is probably due to a greater storage and recovery of energy in the elastic elements as the animals travel at higher speeds.

The tendons and ligaments in the rear limbs and the tail seem admirably suited for storage of elastic energy. The achilles tendon is an extremely large tendon (approximately 1.5 cm in diameter and 35 cm in length in a 40 kg animal which we dissected). Badoux⁴ comments that the very long calcaneus seems to act as a lever for the tendons and ligaments of the achilles formation. As the kangaroo landed at higher speeds,

more force would be applied on this lever causing greater stretching of these elastic elements. Recovery of this stored energy on take-off might well explain the slight decline in oxygen consumption with increasing speed of hopping. It is also possible that other systems play a role in elastic storage of energy as the kangaroo hops, and the classic example of the suspensory or springing ligaments of the horse fetlock comes to mind⁶. Two broad sheets of tendons run along both the ventro-lateral and dorso-lateral aspects of the tail. The ventral tendons appear involved in pulling the tail towards the animal during pentapedal locomotion while the dorsal ones might be involved in elastic storage of energy during hopping.

From our data it is seen that at speeds of less than 18 km h^{-1} the hopping kangaroo expends more energy than a running four-legged animal of the same weight, but at speeds exceeding 18 km h^{-1} it appears to be cheaper to hop. Accurate measurements of speeds at which undisturbed kangaroos ordinarily travel in nature are not available. Kangaroos can, however, travel at speeds considerably faster than the maximum speeds which were possible in our studies. Most observers agree that large kangaroos can sustain speeds of 40 km h^{-1} for several km and may reach 50–65 km h^{-1} in short bursts^{2,6}.

It is difficult to understand why large hopping herbivores are found only in Australia, since hopping appears to be such an inexpensive way to travel at high speeds. The energetics of hopping, however, may give some insight into the survival of the large hopping herbivores of Australia while their quadrupedal counterparts became extinct. Some 20,000 to 30,000 yr ago, before Palaeolithic man arrived in Australia, the marsupial fauna was much more diverse than at present. There were predators such as the marsupial lions (*Thylacoleo carnifex*) and Tasmanian wolves (*Thylacinus cynocephalus*). There were also large quadrupedal herbivores, some of which were the size of a rhinoceros, for example *Diprotodon* sp. One might speculate that the kangaroos were able to sustain higher speeds when being pursued than those other large terrestrial marsupials, as a result of the low energetic cost of hopping. This could explain how they survived the introduction of man and his dog, the dingo, while the large quadrupedal marsupials became extinct.

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Reference Abbreviations

ALL abbreviations of references in *Nature* should now conform to the style of the *World List of Scientific Periodicals*, fourth ed. (Butterworth, 1963–65). Authors submitting manuscripts are asked to ensure that the references are written appropriately.

BOOK REVIEWS

After Kinsey

The Female Orgasm: Psychology, Physiology, Fantasy. By Seymour Fisher. Pp. x+544. (Allen Lane: London, April 1973.) £5.

PROFESSOR FISHER'S book, which deals primarily with the psychology, fantasy and partly with the physiology of the female orgasm, is complementary to the earlier works of Masters and Johnson^{1,2} and Kinsey^{3,4}. Although a significant book by any standards it is not as innovative as its predecessors. The first one-third of the book is divided into five chapters which comprehensively review a commendably large and diverse selection of the literature on the "female sexual response". This is a valuable source of reference for the many workers, medical and non-medical, working in the field.

The remaining ten chapters of the volume contain data that Professor Fisher accumulated prospectively on some two hundred and eighty female volunteers recruited as seven samples. To satisfy different criteria they were studied over differing lengths of time and with somewhat differing procedures. In summary, however, virtually all were subjected to interviews galore, a battery of standard psychological tests, numerous self-rating questionnaires and in most cases physiological measurements, including galvanic skin response (finger, breast, labia, ankle), temperature, heart rate and so on. The sheer volume of data collected was enormous by any standards and allowed diverse statistical analyses.

I am sure Professor Fisher will not take issue with me if I say that the majority of his findings, which are negative correlations, provide more questions than answers, although in general the data accord well with Kinsey's earlier sociological information and the more recent physiological correlates of Masters and Johnson^{1,2}.

What, then, are Fisher's positive findings? Perhaps the most important, since it tends to contradict Masters's insistence of the pre-eminence of the quality of physical stimulation in orgasmic response in the female, is that "a feeling of emotional security and of being loved were more important to the female than were stimulative techniques, prowess of the male, length of foreplay, variation in coital positions, frequency of coitus, and so on". Fisher speculates that this might have psychological roots in childhood when a "demanding and definite (as contrasted with a

casual and permissive) father" made an immutable (sexual) impact. (An implicit plea for an increase in parental discipline?) Unfortunately, Fisher's boldness deserts him less than half a page further on when, winding up the discussion on the genesis of sexual responsiveness, he states "because of the imperfect techniques available for measuring the variables involved, one cannot begin to define realistically how influential these early (parental) transactions are. They could be enormously important and even the prime determinant of orgasmic potential". He clearly believes this even if he does not assert it. In common with those from more recent contributors, Fisher's data surely destroy the old but pernicious psychoanalytical chestnut that vaginal orgasm is better and more mature than clitoral orgasm, which was represented as being neurotic. Fisher provides abundant psychometric data which indicate unequivocally that mental health is not associated either with the "allegedly" differing types of orgasm, or indeed with sexual responsiveness at all. This must be somewhat of a kick in the teeth for the classical psychoanalyst who, in spite of all, continues to maintain that clitoral orgasm is infantile and frigidity is sick.

The book concludes with some practical implications, sub-sectioned under the headings "Pathways to Sexual Adequacy", "Sex Education", "Sexual Adequacy", "Sex and Mental Health", "Treatment of Orgasm Difficulties", "Non Sexual Functions of Sex", "Education", "Sexual Practice Affects"; and pregnancy and priority problems in the study of female sexuality.

A. J. COOPER

¹ Masters, W. H., and Johnson, V. E., *Human Sexual Response* (Little Brown, Boston, 1966).

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⁴ Kinsey, A. C., Pomeroy, W., and Gebhard, P., *Sexual Behavior in the Human Female* (Saunders, Philadelphia, 1953).

Calorific Homeostasis

Regulation in Metabolism. By E. A. Newsholme and C. Start. Pp. xiii+349. (Wiley: New York and London, April 1973.) £6.

THE ability of an organism to adjust selectively the chemical processes taking place in some of its cells in response to the environmental change is of great fascination. This book describes how

the activities of certain enzymes associated with the provision of fuel for oxidation are controlled, or in the words of the authors' preface, the maintenance of "calorific homeostasis". The scope is therefore limited to control of carbohydrate and fat metabolism in, for the most part, mammalian tissues. Control of amino acid, nucleotide and amine metabolism is excluded, as is the role of protein biosynthesis and degradation in those pathways which are covered in this book and the title *Regulation in Metabolism* is thus possibly misleading. One can, however, appreciate the authors' dilemma in attempting to produce a book which deals in depth with the mechanisms by which certain enzymes and hence pathways may be controlled, whilst keeping the scale, and hence price, down sufficiently for students to be able to afford to buy it. A soft-back version would surely be welcome.

The first two chapters cover the theoretical basis of regulation of enzyme activity and metabolite levels (allostery, substrate cycling, enzyme interconversions) and the identification of control points in a pathway. The remaining five chapters deal in detail with the control of carbohydrate metabolism in muscle and liver, and control of fat metabolism in liver and adipose tissue. Although the factual content is high, the text is very readable with a liberal use of tables and diagrams, and more than 400 references are cited. The complexities of intermediary metabolism often bewilder the student but Newsholme and Start have successfully integrated not only those parts of carbohydrate and fat metabolism which overlap, but also some areas of physiology and biochemistry. For example the control during starvation of plasma glucose and fatty acid levels is explained in terms of the action of ketone bodies on (i) lipolysis in adipose tissue, (ii) glucose oxidation in brain and muscle, and (iii) release of insulin from the pancreas. A useful final section covers many of the known biochemical effects of a restricted number of hormones (insulin, growth hormone, adrenaline and glucagon). It would also have been useful if the same treatment had been given to cyclic AMP.

Errors are few and mostly trivial, although the suggestions that (i) the result of donkey spleen deoxycytidine monophosphate deaminase action on dCMP is dAMP, and (ii) valine and isoleucine are degraded to glutamate, should have been spotted. It is also misleading of the authors to state that fatty acid oxidation is the only

physically organised pathway, when recent research is revealing the existence of multi-enzyme complexes containing many or most enzyme activities associated with specific biochemical pathways.

Generally, however, the book is highly recommendable to any undergraduate (or graduate) biology student who has received a basic biochemistry course. It can only serve to increase the student's interest in the mechanisms of biological regulation.

A. R. HIPKISS

Immune Responsiveness

Genetic Control of Immune Responsiveness: Relationship to Disease Susceptibility. Edited by Hugh O. McDevitt and Maurice Landy. (Proceedings of an International Conference held at Brook Lodge, Augusta, Michigan, May 8-10, 1972.) Pp. xviii+469. (Academic: New York and London, April 1973.) \$19.50.

THIS handy book presents the well planned, three-day discussion on the genetic control of immune responsiveness which took place at Brook Lodge in May 1972. It is well designed, and excellently edited by H. O. McDevitt and M. Landy. The book does more than document the symposium; it gives a systematic and comprehensive survey of the genetics of immune responses, different aspects of which are treated precisely by scientists, eminently competent in their respective fields, whose names are often synonyms for their work. The discussions themselves do not simply paraphrase the material presented, but elaborate new views. The book avoids the common tedium of conference reports, and can serve as a text and reference book, both of which are lacking in this area. In this context, however, references to original papers would be desirable.

The six chapters (followed by an extensive commentary by M. Cohn) deal with histocompatibility-linked Ir genes, the H-2 region, Ir genes linked to allotypes, T and B cell receptors, control of disease susceptibility and HL-A type and disease. This classification is practical and also delineates principal aspects of genetic control of immune responsiveness as we see them today.

Immune response (Ir) genes are distinguished genetically and functionally as histocompatibility and as immunoglobulin-heavy chain allotype-linked genes. Several models of genetic control cannot, however, yet be classified (Sela, Biozzi). The histocompatibility-linked Ir genes are interpreted as dealing with the specific recognition of antigens by T cells or even determining the T cell receptor itself (Benacerraf, McDevitt). This concept, of course, leads to an extensive discussion of the nature of the

T cell receptor: immunoglobulin *pro* and *con* (Unanue, Uhr, Warner). The question remained open.

The major histocompatibility systems of mouse (H-2) and man (HL-A) are introduced by Shreffler and Ceppellini, respectively. As illustrated by F. Bach and van Rood, serologically defined H antigens are distinct from other functions of these gene regions; that is, MLC (mixed lymphocyte culture) stimulation, graft rejection, genetic control of immune response. Some examples of allotype linked control presumably reflect presence or absence of the respective structural genes (*v* genes) for receptors on B lymphocytes (Cohn, Nisonoff). But other types might represent still unknown mechanisms (for example, monoclonal antibodies, Krause).

The concept of Ir genes has important theoretical and medical implications. It might be the key to a new analytical approach to studying susceptibility to infectious, autoimmune and neoplastic diseases, at least as far as immune reactions are involved. Lilly gives an example of how multigenic control already can be analysed (Friend virus disease). It is further shown that genetically controlled immune responses can either prevent or cause virus disease (Oldstone). In man, only studies on the population level of associations between HL-A system and disease are reported (Bodmer). Family studies, such as Levine's on pollen allergy, are not yet included in this book.

Bodmer presents a stimulating genetic model for major histocompatibility systems: that is, large clusters of related genes, which presumably arose by evolutionary gene duplications and which control functions such as graft rejection, MLC stimulation, disease susceptibility, antigen recognition and serologically detectable H antigens. Associations at the population level then reflect linkage disequilibria between closely linked genes.

M. Cohn systematically summarises the theoretical implications of genetic control of immune responsiveness and their bearing on generation of diversity and self-tolerance in terms of his theory of associative recognition. This is literally a purgatorium of all facts and ideas presented before. Cohn makes explicit (and the book implicit) that facts must be separated from contaminating tacit assumptions and also that they become meaningful only within a conceptual framework, which prevents them from becoming misleading.

The reader, overwhelmed by data and interpretations, may be consoled by a sentence (easily generalised) from F. Bach: "Who isn't confused about MLC isn't thinking clearly" (he might even become proud of it).

E. GÜNTHER

Electrochemistry

Electrochemical Systems. By John S. Newman. Pp. xiv+432. (Prentice-Hall: Englewood Cliffs, New Jersey, January 1973.) \$18.95.

READING this book emphasises the range of the study of electrochemistry and the possibility of creating interest by the nature of the attitude adopted to create coherence in the subject.

The approach is predominantly that of the chemical engineer; illuminating at times but rather insensitive in those areas where the chemistry of the materials could be involved as a major interest, and with an indifference to techniques of experimentation. The result is an interesting and in some ways quite a valuable book; a good companion to more conventional texts and certainly, and of course deliberately, more comprehensive in coverage than is customary. Thermodynamics, electrode kinetics, electrokinetics, ionic transport processes, current distribution and mass transfer are treated.

The author is happiest in his exposition of phenomena which may be described and satisfactorily handled by a formal treatment; essentially areas, as defined by the author on page 1 of the book, where electrochemistry may be regarded as macroscopic science in the absence of a need for correlation with microscopic or molecular concepts. This is strongly to be contrasted with the approach to electrochemistry as followed by some more chemically oriented authors, in which the interest is essentially atomistic and preoccupied by adsorption and electron transfer; these are difficult electrochemical problems, germane to a full understanding of the interfacial processes but, no matter how complex the treatment, not yet yielding to a theoretical approach.

Many practising electrochemists will read the contents of this book relating to the handling of the macroscopic aspects of the subject with interest and benefit; the chemical engineer, diverting his thoughts to electrochemistry, in particular should become happier in certain aspects of the application of his professional skills. It would be kind, however, to omit comment on the chapter on electrode kinetics, a section most necessary to such a continued education.

A feature of the book and one according to the American pattern is the rather extensive lists of examples at the end of each major section. I regard them with mixed feelings. It is a respected pedagogic procedure to provide students with such exercises but the value is purely much diminished in the omission of answers and even some guidance to the solution of some of the questions. Some, too, refer to unrealistic experimental situations which,

one would have thought, applied scientists should be taught to avoid.

In all, a useful book bringing a refreshing, if formal, approach to a number of problems.

H. R. THIRSK

Dividing and Developing

The Cell Cycle in Development and Differentiation. Edited by M. Balls and F. S. Billett. Pp. xi+483. (Cambridge University: London, May 1973.) £11.

THIS volume contains twenty-six papers concerned with some biological aspects of cell division and the cell cycle in plants, protozoa, and some species of multicellular animals. The editors state in their preface that the book is intended to complement that of Mitchison (*The Biology of the Cell Cycle*, Cambridge University Press, London, 1971) which summarises what is known of the cell cycle in prokaryotes as well as in synchronous cell populations of eukaryotes and of vertebrates *in vitro*.

There are two general reasons why a knowledge of the cell cycle may be important in the study of cell differentiation. One is that there are cyclic variations in some kinds of nuclear or gene activity, and these are related to stages of the cell cycle. Cyclic variations of this kind have been clearly established for DNA synthesis, histone synthesis, and certain kinds of enzyme activity. It is clear, however, that there is not yet sufficient information to say whether gene activity is in general regulated in this cyclic way. In view of the recent development of sensitive methods of determining the amounts of newly synthesised messenger RNAs of known kinds, it should now be possible to determine for several different genes whether their expression fluctuates consistently within a cell cycle, either at the level of transcription, translation, or post-translational modification. Until much more information of this kind is available it is hard to plan clear-cut experiments designed to analyse the relationship of the cell cycle to gene expression in molecular terms.

The other interesting question relating the cell cycle and cell differentiation concerns the possibility of a connection between a certain phase of the cell cycle such as mitosis or DNA synthesis and the induction of new gene expression. Many authors have suggested within the last 10 years that cells must pass through a phase of DNA synthesis or a mitosis, between the time when a cell is acted upon by an inducer of differentiation (such as erythropoietin) and the time of realisation of that differentiation (in this case haemoglobin synthesis). If true, this relationship could be of great importance in understanding cell differentiation. At present, however, there is no

experimental system which is ideally suited to the investigation of this question. In this symposium only the paper of Harrison *et al.* is concerned directly with this potentially important matter.

In view of the lack of information about changes in gene activity during the cell cycle, it is not surprising to find that most contributors have given what amounts to a descriptive account of variations in the frequency or duration of a cell cycle in the developing system of their choice. These include Bennett (plant meiosis), Barlow (plant root meristem), Lynden (plant shoot apex), Biggelaar (mollusc development), Rudkin (insect polytene chromosomes), Chibon (newt embryos), Graham (early mouse development), and Steel (cultured human cells).

Some other contributors have described patterns of RNA synthesis or of enzyme activities which are characteristic of tissues composed of cells mostly at a known stage of the cell cycle. Examples of papers in this category are those of John *et al.* (*Chlorella*), Grant (*Physarum*), Yeoman and Aitchison (cultured plant cells) and Giudice (sea urchin oocytes).

Only a very few authors have attempted a truly experimental analysis of factors which cause cyclic changes in nuclear or gene activity. A shining example of this is the elegant work of Ord, involving nuclear transfers in *Amoeba*. In addition Grant describes attempts to obtain changes in the activity of isolated nuclei.

The volume ends with a few very useful summaries of subjects which are of topical, though sometimes controversial, interest: for example, Harrison *et al.* and Cole and Tarbutt (erythropoiesis), Hardy and Ling (mitotic activation of mammalian lymphocytes), Harris and Olsen (metabolic DNA), and Rytömaa (chalones).

It is principally the thorough review articles with an ample supply of references which justify publication of symposia such as the one under review. Apart from containing a number of such articles, this symposium succeeds well in bringing together work on a wide range of eukaryote organisms. I think it will form a useful addition to the library of those interested in the cell cycle and in some aspects of development.

J. B. GURDON

Rat Adenohypophysis

Ultrastructure of Rat Adenohypophysis: Correlation with Function. By Allen Costoff. Pp. xiii+220. (Academic: New York and London, February 1973.) \$14.50.

THE twelve chapters in this book, in addition to an introduction, describe the experimental procedures used by the

author; the several types of glandular cells of the pars distalis (a chapter being allocated to each); the pars tuberalis; the pars intermedia; the biochemical properties of isolated granules and the morphological aspects of the secretory process. Extensive bibliographies are provided at the end of each chapter and there are many electron micrographs of varying quality.

It is obviously difficult to write a book of this type; and, in this instance, because of the rigid subdivision of the topics the work lacks coherence. A final chapter giving a critical appraisal of the significance of the numerous observations referred to in the text would have been of great value. The lack of such a critical assessment is, to my mind, a serious defect in a book which, although it provides much information, fails adequately to emphasise what is significant or, indeed, acceptable. An example of this is to be found in the chapter on the adrenocorticotrophic cell, where in the same section, having stated that certain Japanese workers had reported the dimensions of the secretory granules to be about 200 μm in diameter, the author (from his own observations) reports them to be about 106 μm . This discrepancy passes without comment and one therefore wonders whether, in fact, the same kind of cell is being described.

Finally, very little indeed is said about the ultrastructure of the non-glandular components of the pars distalis-interstitial (stellate) cells, the connective tissue and its associated cells, the blood vessels and their perivascular spaces, and basement membranes. These topics do not appear in the index.

In summary, this book is a compilation of observations unaccompanied by any serious attempt at evaluation.

C. L. FOSTER

Radiation

Radiation Chemistry. By A. J. Swallow. Pp. xi+275. (Longman: London, January 1973.) £5.50.

THIS book aims to provide an overall picture of the whole field of radiation chemistry, and is intended not only for radiation chemists but also for readers whose main interests lie in subjects related to radiation chemistry, ranging from nuclear technology and radiation physics through photochemistry and chemical kinetics to polymer science and radiation biology. The encompassing of such a broad field is a considerable task, and the author has kept the length of the book within bounds by the expedient of discussing illustrative examples of typical work rather than presenting a detailed survey of each topic. Thus the book is aimed at the beginner rather than the expert.

The author begins with a short account of natural and artificial sources of radiation, which includes brief descriptions of the working principles of nuclear reactors, X-ray machines and particle accelerators. Next come chapters on the absorption of radiation in matter and on dosimetry. Chapter 4 is a description of the manner in which the primary species of excited molecules, electrons, positive ions and free radicals are produced as a result of radiation absorption by matter, and of the extent and importance of their roles in the ensuing processes. Brief descriptions of the methods by which such short lived intermediates are observed include electron spin resonance spectroscopy, mass spectrometry and pulse radiolysis. This chapter lays the foundation for the succeeding chapters which deal with the particular systems of inorganic solids, gases, water and aqueous solutions, organic compounds, polymeric systems and substances of biological interest. These topics reflect the broad scope of the book, which should give newcomers to radiation chemistry a good introduction to the whole range of the subject, as well as provide radiation chemists with useful starting points in areas outside their specialised fields of research.

The book is produced in an easy style with good use of footnotes and cross referencing in the text. Selected references to other works are given at the end of each chapter, and there is a good subject index and a useful appendix of units and conversion factors. The author has set a number of problems, with answers, at the end of each chapter which should aid the reader in his understanding of the subject. The book is well illustrated, and there are several quite extensive tables of data on such quantities as bond energies, proton and electron affinities and rate constants which would seem more appropriate to a reference work.

On the whole this is a book to be recommended and it should find a place in most science libraries.

G. V. BUXTON

Quantitative Materials

Problems in Materials Science, Vol. 1. Edited by H. D. Merchant. Pp. x+476. (Gordon and Breach: New York, London and Paris, 1972.) £12.30.

ONE of the interpenetrating pecking orders that bedevil life in universities is the hard science/soft science hierarchy. Ever since Lord Kelvin uttered his memorable chestnut about the impossibility of knowing anything properly unless one can measure it, the applied mathematicians and their imitators have played upon the inferiority complexes of the botanists, mineralogists, zoologists, metallurgists and many others. Each of the sciences has become pro-

gressively more quantitative, and this is a natural and inevitable progression. What can be seriously misleading is the suggestion that close observation, pattern perception, the recognition of correlation between events (whether or not correlation coefficients are estimated) are no part of the stuff of science but rather a kind of pre-scientific pap. The quantitative approach is central to science and has been at least since the time of Tycho Brahe, but so is the skill of the close observer. Tycho Brahe and Johannes Kepler are coupled in scientific history.

This slightly exaggerated outburst is prompted by contemplation of the volume under review. The editor complains that metallurgy or materials science is apt to be taught in a qualitative manner, and to counteract this he intends the book as "an aid to solving problems". Individual authors deal with fields such as diffraction, diffusion, nucleation and growth, thermodynamics, interfaces, magnetic fields, mechanical testing. Each chapter has an introduction which is essentially a minitext on quantitative aspects of the field, then some problems are solved *in extenso*, finally a number of bare problems are added, without solutions.

Certainly a skilled university teacher can mine this quarry and find a number of helpful problems to illustrate his own systematic teaching, though it must be said that for this purpose a complete set of model answers would have been distinctly helpful. But it is hard to see how a student (final-year undergraduate or first-year graduate, at whom the book is aimed) could possibly hope to cope with more than a modest fraction of the (mostly) very advanced subject matter. Complicated tensor treatment of crystal elasticity jostles with first-principle estimates of elastic moduli of various rubbers, the Boltzmann transport equation and its implications, and the advanced treatment of thermal vibrations. No undergraduate I have ever encountered in the materials field could (or should be expected to) cope with some of this subject matter, though other parts, such as Tegart's treatment of mechanical testing or Nussbaum's of magnetic fields, should be more readily accessible.

The impulse which led to the writing of this book is entirely understandable, but the consequent search for particularly quantitative fields has led to a choice of topics and a level of treatment which are generally more appropriate to a graduate theoretical physics course. This is not materials science, but parts of the book (rather less than half, probably) can be used by an experienced teacher in the field as useful source material. The book cannot be recommended for self-study.

The names of two of the contributors

(McLean and Tegart) are misspelled and the page numbers in the table of contents are incorrect.

R. W. CAHN

Canadian Fish

Pacific Fishes of Canada. (Bulletin 180: Fisheries Research Board of Canada, Ottawa.) By J. L. Hart. Pp. ix+740. (Information Canada: Ottawa, 1973.) \$8.

THE study of the fish fauna of the North Pacific commenced with the explorations of the Imperial Russian expeditions of the early nineteenth century, and while some of the fishes described, such as the salmon, *Oncorhynchus* spp., occur on the Canadian Pacific coast, knowledge of that fauna was sparse until almost the present century. Such descriptions as existed were the result of British surveying expeditions, and later of the work of the early school of American ichthyologists, notably D. S. Jordan and C. H. Gilbert.

This history resulted in the literature on Canadian Pacific fishes being scattered through numerous sources until 1946 when Clemmens and Wilby published the first faunistic treatment of the region. The publication of their *Fishes of the Pacific Coast of Canada* stimulated further research and a second, revised edition appeared in 1961. The present volume by J. L. Hart, although ostensibly a lineal descendant of Clemmens and Wilby's book, is an original work and a totally new synthesis of the literature. The contents are organised systematically, each species is well illustrated with new and excellent drawings, and major headings include a description, life history, and distribution. The description is the conventional listing of body proportions but has subsections for meristic data for fin elements and scales, as well as colour notes. A most helpful innovation is the separate heading "Recognition" where characteristic features are itemised. Dichotomous keys to families or orders are clearly set out with quite unambiguous couplets and there are general keys to the classes of fish treated.

Up to date faunistic treatments are of fundamental importance and, with this new work, the Canadian fish fauna is one of the most competently and exhaustively treated. Hart's book will be of great value to fishery workers and students of other disciplines, for it is a modern synthesis of high standard. The author is to be congratulated on the conciseness and clarity of presentation of his material, and the editorial staff of the Fisheries Research Board of Canada deserve commendation for their foresight in commissioning such a fundamental work and for producing it at a very reasonable price.

ALWYNE WHEELER

TELEVISION REVIEW

Black Holes— Authorised Version

QUICK on the heels of October's *Horizon* programme about black holes, the BBC last week presented *Not Seeing Is Believing*, a fifty-minute lecture about black holes by Dennis Sciama of Oxford University. The *Horizon* programme (see *Nature*, **245**, 467; 1973) should really have been billed as a programme about gravity in general. Black holes were not mentioned until near the end, when the presenter, John Taylor of King's College, London, was seen draped over flagstones bordering the ornamental pond at Herstmonceux, uttering profound thoughts about black holes in this Universe being white holes in the next, and so on.

Anyone left mystified by John Taylor (and there must have been many) should have turned to Dennis Sciama for a clear account of the basics—what black holes are, why astronomers think black holes should exist, how we might look for them, and their generally-agreed properties. But it was strictly for *aficionados* of astronomy; right at the beginning we had supernovae, radio galaxies, and quasars, without any definitions at all, and soon we were onto event horizons and the language of the astrophysicist.

On top of that there is the difficulty of turning a lecture into good television. Sciama was speaking before an audience of students at St Andrews University—not in an intimate lecture theatre, like the cosy one at the Royal Institution in London that has often been used by the BBC, but in one of those places with a long demonstration bench in front of an array of blackboards.

This problem was overcome by illustrating the lecture with animated drawings projected onto a huge screen above the speaker. These moving drawings were accompanied by a recorded commentary by Dr Sciama, in a more tranquil tone than his lecture theatre voice, that nicely broke up the forceful delivery of the rest of the lecture. The animated drawings—actually not much more complicated than blackboard sketches—themselves contributed a lot to the programme. We saw matter being swept into black holes, gravitational waves being emitted as a star collapsed, and two black holes coalescing, each developing a proboscis like a Gerald Scarfe cartoon of Edward Heath's nose. It was a neat way of coping with the lecture format, and the white drawings on the black background of the screen seemed particularly appropriate for theoretical astrophysics.

The programme was altogether a very creditable performance. It was presented by the Open University in conjunction with the Royal Astronomical Society, and shown during the Open University's television time. It is, however, very much the kind of programme that graduates of Patrick Moore's late-night astronomy programme would appreciate.

It is also good to see the Royal Astronomical Society taking a part in bringing the excitement of modern astronomy before the public. The society has recently become interested in astronomy education, and this lecture is meant to be the first of a series of public expositions on modern developments in astronomy, the society suggesting the topic, supplying the speaker, and paying his fee. The Royal Astronomical Society is perhaps the most entrancing of the scientific societies in London, even allowing for the transfer of its meetings from its own lecture room in Burlington House to the more cosy but less magical Scientific Societies Lecture Theatre in Saville Row; it has an enthralling history, and its members are carrying out some of the most exciting research work that is going on today. The society ought to be better known to the public.

EDWARD PHILLIPS

CORRESPONDENCE

Open Journal

SIR,—May I suggest for *Nature* a radical, healthy change in what I regard as an essentially ailing magazine (not a journal, while present policies persist)? You say (*Nature*, **244**, 475; 973) "*Nature* must be an open journal, reflecting the sense of community which is very strong among scientists." If you mean what you say, my advice is that you should sign your editorials, strip the sobriquets from your coyly labelled "Cell Biology Correspondent", etc., and publish a masthead. Then we can start talking about an open journal.

The snide sharpshooting from behind shields of anonymity, which has become so characteristic of *Nature* that it is now known in many circles as *Ill-Nature*, is, I am convinced, a direct result of a smug journalistic tradition of anonymity which is totally out of place in a scientific publication and which other scientific journals have long abandoned. Do you in fact stand

behind your own "fine words"? Are you a man, a mouse, or a gnome? How can we tell, when you don't even tell us your name? Are we mortals who have names to conclude you're God? Or that you think you are? Do you dare to print this letter? At least you know who it comes from, since I am not afraid to sign myself

F. PETER WOODFORD

1 Akenside Road,
London NW3 5BS

Nature will have a masthead in January. Full biographical details appeared earlier this year (**243**, 110; 1973) from which readers may care to deduce more about my personality. They may also assume that I write the leaders in constructing their identikit of me.—ED.

Arginine Deficiency

SIR,—In the background information to the discussion on orotic aciduria and arginine deficiency, Milner and Visek

stated¹ that Scull and Rose had shown² that "the growing rat . . . requires arginine for optimum nitrogen retention and normal growth." In point of fact, Scull and Rose had concluded³ that arginine was not required by the rat. The initial data on the essential nature of arginine were based on studies with chicks³.

Yours faithfully,

A. ARNOLD

Rensselaer, New York

¹ Milner, J. A., and Visek, W. J., *Nature*, **245**, 211 (1973).

² Scull, C. W., and Rose, W. C., *J. biol. Chem.*, **89**, 109 (1930).

³ Arnold, A., Kline, O. L., Elvehjem, C. A., and Hart, E. B., *J. biol. Chem.*, **116**, 699 (1936).

A list of books received will appear in the January 4 issue of *Nature*.

Announcements

University News

Professor Edward Parkes has been appointed Vice Chancellor of the City University to succeed Sir James Tait.

Dr B. J. Aylett has been appointed Professor of Chemistry at Westfield College, University of London.

Dr M. Sandler has been appointed Professor of Chemical Pathology at the Institute of Obstetrics and Gynaecology, University of London.

Dr T. A. Sears has been appointed Professor of Neurophysiology at the Institute of Neurology, University of London.

Dr R. L. Smith has been appointed Professor of Biochemical Pharmacology at St Mary's Hospital Medical School.

Professor J. P. Quilliam has been elected Chairman of Convocation of the University of London to succeed Sir Charles Harris.

Dr John Knott, University of Cambridge, and Dr Richard Dolby, The Welding Institute, have been awarded the 1973 L. B. Pfeil Prize of the Iron and Steel Institute and the Institute of Metals.

Miscellaneous

The following have been awarded The National Medal of Science of the United States: Daniel I. Arnon (University of California); Carl Djerassi (Stanford University); Harold E. Edgerton (MIT); William Maurice Ewing (Marine Biomedical Institute, University of Texas); Arie Jan Haagen-Smit (California Institute of Technology); Vladimir Haensel (Uni-

versal Oil Products Company); Frederick Seitz (The Rockefeller University); Earl W. Sutherland, Jr. (University of Miami); John Wilder Tukey (Bell Laboratories and Princeton University); Richard T. Whitcomb (NASA) and Robert Rathbun Wilson (National Accelerator Laboratory).

Professor David T. Griggs of the University of California at Los Angeles has been awarded the Arthur L. Day Medal of the Geological Society of America.

Dr M. King Hubbert of Stanford University has been awarded the Penrose Medal of the Geological Society of America.

The Gas Chromatography Discussion Group is no longer associated with the Institute of Petroleum and is now called the Chromatography Discussion Group.

International Meetings

December 10, New Polymers from Silicate Materials (The Assistant Secretary, Society of Chemical Industry, 14 Belgrave Square, London SW1X 8PS).

December 12-13, Symposium on the Humber Estuary (Dr N. V. Jones, Department of Zoology, The University of Hull, Hull HU6 7RX).

Reports and Publications

not included in the Monthly Books Supplement

Great Britain and Ireland

The British Non-Ferrous Metals Research Association. Annual Report for 1972. Pp. 48. (London: The British Non-Ferrous Metals Research Association, 1973.) [117]
World List of Films on Bees and Beekeeping. provision edition. Pp. vii+67. (London: Bee Research Association, 1973. Obtainable from Bee Research Association, Hill House, Chalfont St. Peter, Gerrards Cross, Bucks.) 50p; \$1.50. [117]
Scientific Instrument Manufacturers' Association of Great Britain. 56th Annual Report, 1972/1973. Pp. 22. (London: Scientific Instrument Manufacturers' Association of Great Britain, 20 Peel Street, W8, 1973.) [127]

Sampling in the Mineral and Metallurgical Processing Industries. (Papers presented at a meeting held in London on 2 July 1973.) Pp. 65. (London: The Institution of Mining and Metallurgy, 44 Portland Place, W1, 1973.) £5. [127]
Central Statistical Office. Research and Development Expenditure. (Studies in Official Statistics No. 21.) Pp. 136. (London: HMSO, 1973.) £1.55 net. [127]
Forestry Commission. The Marketing of Forest Tree Seed and Plants within the European Economic Community. Pp. 8. *Gratis*. Leaflet No. 55: Hydratongs. By F. B. W. Platt and P. Wood. Pp. 10. 10p net. Leaflet No. 56: Grey Squirrel Control. By Judith J. Rowe. Pp. 17. 12p net. Leaflet No. 57: Replacement of Elm in the Countryside. By A. F. Mitchell. Pp. 4. 4p. Research and Development Papers. No. 94: Cablecrane Design Studies. By D. Biggs. Pp. iii+52. No. 95: Some Aspects of Recreation Planning in the Forestry Commission. By A. J. Grayson, R. M. Sidaway and F. P. Thompson. Pp. 16. No. 96: Construction and Application of Stand Yield Models. By G. J. Hamilton and J. M. Christie. Pp. 14. No. 97: Report of a Working Party on Lorry Transport of Roundwood. By P. C. Ormrod and P. C. Stern. Pp. 22. Forest Commission Library Review, No. 25, April 1973. Pp. i+28. (London: Forestry Commission, 1973.) [127]

Other Countries

US Department of the Interior: Geological Survey. Bulletin 1332-D: Lithologic Characteristics of Pliocene Rocks Cored at Elk Hills, Kern County, California. By William M. Berryman. Pp. iii+56+plate 1. (Washington, DC: Government Printing Office, 1973.) [187]
Smithsonian Contributions to Zoology, No. 144: The Behavior of Ocellated Antbirds. By Edwin O. Willis. Pp. 57. (Washington, DC: Smithsonian Institution Press, 1973. For sale by US Government Printing Office.) 90 cents. [187]
Gesellschaft für Strahlen- und Umweltforschung MEH, München. Jahresbericht 1972. Pp. 229. (München: Gesellschaft für Strahlen- und Umweltforschung MEH, 1973.) [207]
National Research Council of Canada. Report of the President, 1972/1973. Pp. 121. (Ottawa: National Research Council of Canada, 1973.) [207]
The Year Book of the International Council of Scientific Unions, 1973. Pp. 135. (Paris: International Council of Scientific Unions, 1973.) [207]
Publications du Centre National pour l'Exploitation des Océans. Serie: Rapports Scientifiques et Techniques. No. 15: L'Elevage de la Seriole au Japon. Par A. Muller-Feuga. Pp. 53. (Paris: Centre National pour l'Exploitation des Océans, 1973.) [207]
CERN-European Organization for Nuclear Research. CERN 73-7: Etude d'Un Detecteur pour des Particules de Hautes Energies-La Chambre a Projection Tridimensionnelle. Par A. Breskin. Pp. vi+135. (Geneve: CERN, 1973.) [237]
United States Department of the Interior: Geological Survey. Professional Paper 646-C: Gravity, Magnetism, and Geology of the San Andreas Fault Area, Near Cholame, California. By W. F. Hanna, S. H. Burch and T. W. Dibblee, Jr. Pp. iii+29+4 plates. (Washington, DC: Government Printing Office, 1972.) [237]
The Geological Society of America. Publications Catalog 1973/74. Pp. 83. (Boulder, Colorado: The Geological Society of America, 1973.) [237]
Centre National pour l'Exploitation des Océans. Rapport Annuel 1972. Pp. 80. (Paris: Centre National pour l'Exploitation des Océans, 1973.) [237]

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